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ACIDITY AS A FACTOR IN DETERMINING THE DEGREE OF SOUNDNESS OF CORN.

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INTRODUCTION.

In January, 1910, the Office of Grain Standardization, Bureau of Plant Industry, undertook the investigation of corn (maize) acidity. At that time it was generally known that in all cases the amount of acid or the degree of acidity found in badly damaged or spoiled corn was far greater than the amount of acid or the degree of acidity found in corn which was sound and in good condition. This fact was well established by the researches of Black and Alsberg,[1] of the Department of Agriculture, and by the work of foreign chemists and other investigators [2] on the toxicity of spoiled corn.

It was for the purpose of ascertaining the range in the degree of acidity of commercial corn and to determine the reliability of the acid test as a criterion of quality and soundness of corn from the standpoint of commercial grading that the investigation herein described was undertaken.

METHOD, APPARATUS, AND REAGENTS.

DESCRIPTION OF METHOD.

Select a representative sample (about 100 grams) of corn to be tested and grind to such fineness that at least 80 per cent will pass through a 2-millimeter sieve. Weigh accurately duplicate samples of 10 grams and transfer each to a 300 c. c. wide-mouthed Erlen-

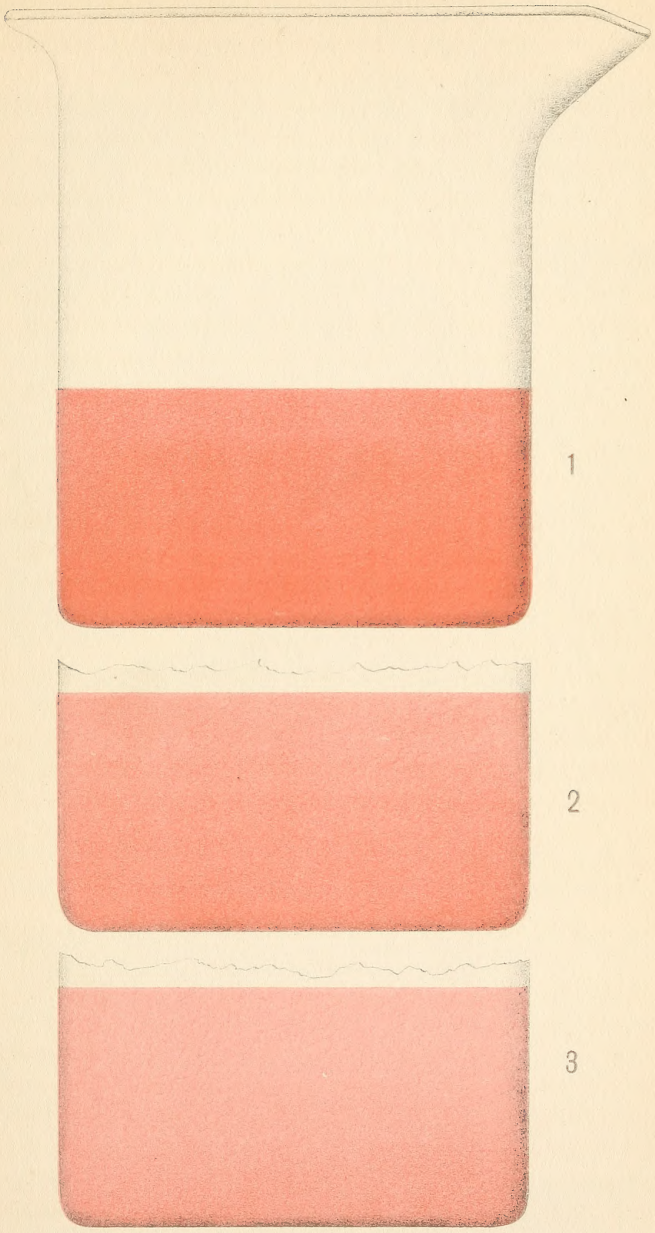
[1] Black, O. F., and Alsberg, C. L. The determination of the deterioration of maize, with incidental reference to pellagra. U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 199, 36 p., 1910.

[2] Schindler, Josef. Anleitung zur Beurteilung des Maises und seiner Mahlprodukte mit Rücksicht auf ihre eignung als Nahrungsmittel. Innsbruck, 1909, 43 p., 1 pl.

Note.—This bulletin shows how the acid test may be used in the commercial grading of corn; it intended for chemists, grain buyers, and all who are interested in grading corn, more especially in the corn belt and at terminal markets.

meyer flask, then add 50 c. c. of 80 per cent alcohol, specific gravity 0.86, and stop the flask tight with a cork or rubber stopper. In order that the meal may be thoroughly and equally subjected to the action of the alcohol, carefully shake the flask with a whirling motion, avoiding a distribution of the meal on the sides of the flask. After shaking, let the meal digest in the alcohol over night (approximately 16 to 18 hours). After digestion filter through a dry filter paper. Place 25 c. c. of the clear filtrate in a 250 c. c. beaker and add 75 c. c. of distilled water and 1 c. c. of phenolphthalein solution and titrate with a one-hundredth normal alkali solution. The proteids dissolved in the alcohol are thrown out of solution when water is added, leaving a white precipitate, which makes it difficult to determine just what constitutes an end point in the titration. The end point that has been adopted is perhaps a slight degree over the point of neutrality, but it is necessary to carry the titration to a distinct color in order to get comparable results. This titration, as will be readily seen when making the determination, is different from most titrations, owing to the cloudy white precipitate formed on the addition of water to the alcoholic extract, which in a measure obscures the color. It will, however, be necessary to analyze corn ranging in color from pure white to deep yellow, where in each case the color of the extract is slightly different. One also has to deal with mixtures of white and yellow corn, where again another colored extract results, depending upon the relative quantity of white and yellow corn present in the sample. Plate I will help persons who perform this analysis for the first time to get the correct color. The colors shown represent titrations of yellow, mixed, and white corn, and it will be seen that the color of the liquid obtained at the end point is slightly different in each of the three cases. It is not expected that persons making this test shall match these colors exactly, but they are intended to give one as clear an idea of the color as can be shown on paper.

To correct the reading of the burette for the acid contained in the alcohol and phenolphthalein, make a blank by taking 25 c. c. of alcohol, 75 c. c. of distilled water, and 1 c. c. of phenolphthalein solution and titrate in the same manner as the corn extract. Subtract the reading thus obtained from the reading obtained by titrating the corn extract, and the result will represent the true acidity in 5 grams of corn. Multiply this result by 2, and it will represent the number of cubic centimeters of one-hundredth normal alkali required to neutralize the acid in 10 grams of corn, or the number of cubic centimeters of normal alkali required to neutralize the acid in 1,000 grams of corn. This result is termed the "degree of acidity" of the corn.



APPROXIMATE COLORS DETERMINING THE END POINT IN TITRATION OF CORN ACIDITY. FIG. 1.—COLOR AT END POINT IN TITRATION OF YELLOW CORN. FIG. 2.—COLOR AT END POINT IN TITRATION OF MIXED CORN. FIG. 3.—COLOR AT END POINT IN TITRATION OF WHITE CORN.

APPARATUS.

A special apparatus is being perfected whereby the time of making acidity determinations can be reduced to approximately 30 minutes.

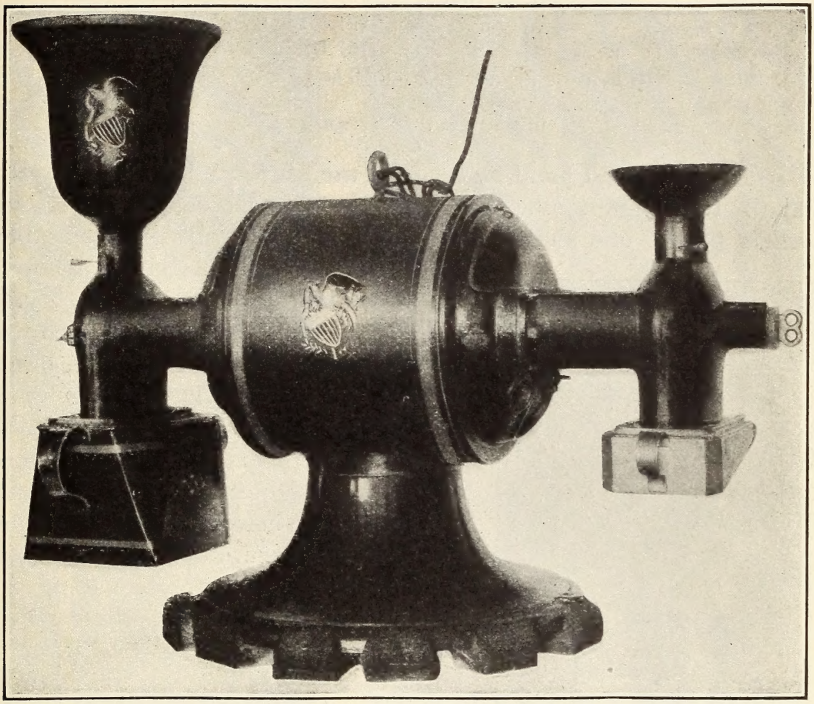


FIG. 1.—Power mill for grinding samples of corn.

Some mechanical defects have been found in the apparatus used in the preliminary investigations and further experimental work is

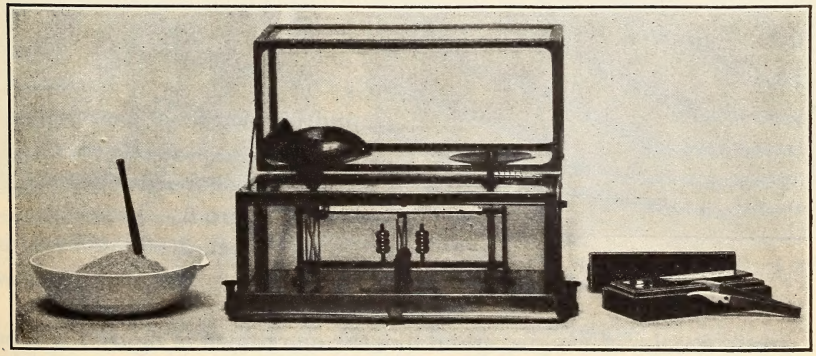


FIG. 2.—Balance, weights, and spatula.

necessary in order to correct these defects before the department would be justified in making a definite announcement.

LIST OF NECESSARY APPARATUS.

(1) Mill.
(2) Balance.
(3) Erlenmeyer flasks, cork or rubber stoppers to fit.
(4) Pipette, 50 c. c.
(5) Funnels, 3-inch.
(6) Graduates, 25 c. c.
(7) Beakers, 250 c. c.
(8) Burette, 50 c. c.
(9) Filter stand.
(10) Hydrometer, reading between 0.700 and 1,000.

DESCRIPTION OF APPARATUS.

Mill.—Any small hand mill can be used for grinding the samples, but where a large number of samples is to be handled, a power mill similar to the one shown in figure 1 is practically indispensable. Any make of power mill similar to the one illustrated will be found satisfactory.

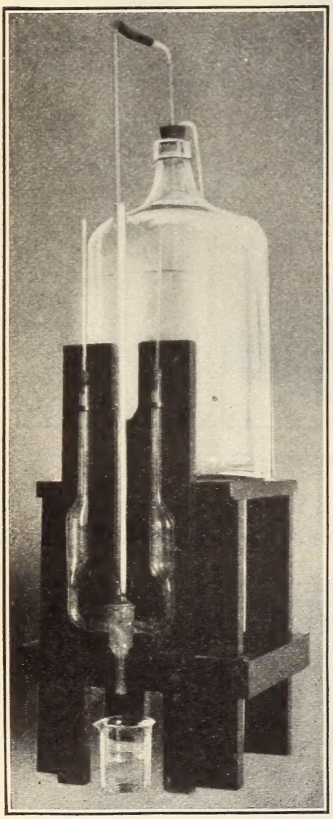


FIG. 3.—Bailey's automatic pipette (75 c. c.) connected with bottle of distilled water.

Balance.—Any chemical balance will answer for weighing the samples, but a balance like the one illustrated in figure 2 will greatly facilitate the work and will be found accurate and speedy and not as complicated as most chemical balances.

Pipettes.—Where only a few samples are to be analyzed, a 50 c. c. standardized pipette will serve for adding the alcohol, but where many samples are to be analyzed an automatic 50 c. c. burette, such as is illustrated in figure 4, will be a decided advantage. An ordinary standardized 75 c. c. pipette will suffice for measuring the water, but where many samples are to be handled an automatic 75 c. c. pipette (illustrated in fig. 3) will be a great help both in time and accuracy.

Burettes.—A 50 c. c. Squibbs burette will be found very satisfactory in titrating (fig. 5)

Filter stand.—A convenient filter stand is illustrated in figure 6. It accommodates 60 funnels and graduates and is a great space saver over many other types.

Drain stand.—A wooden stand like the one shown in figure 7 will be a great help in drying and protecting the glassware. This model can be easily moved about, enabling one to move many flasks or beakers at once, thus saving many steps and valuable time.

REAGENTS.

(1) Eighty per cent alcohol: The specific gravity of commercial 95 per cent alcohol is about 0.816. To make 80 per cent alcohol put

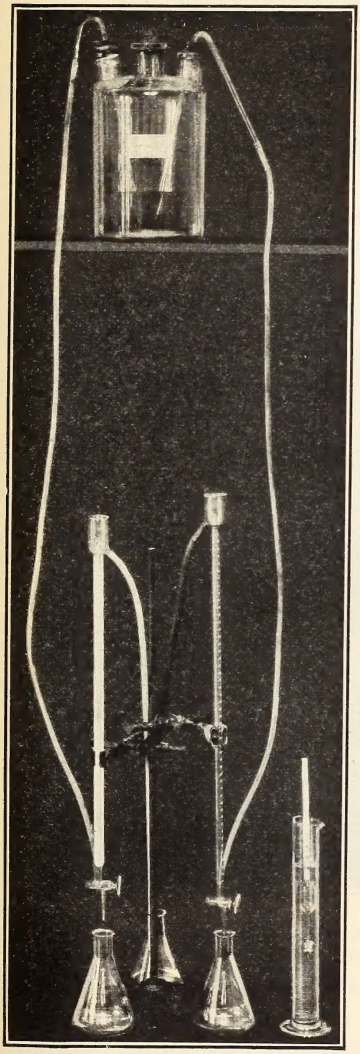


FIG. 4.—Automatic burette of 50 c. c. capacity used in adding 80 per cent alcohol. Hydrometer and cylinder used for preparing alcohol shown at the right.

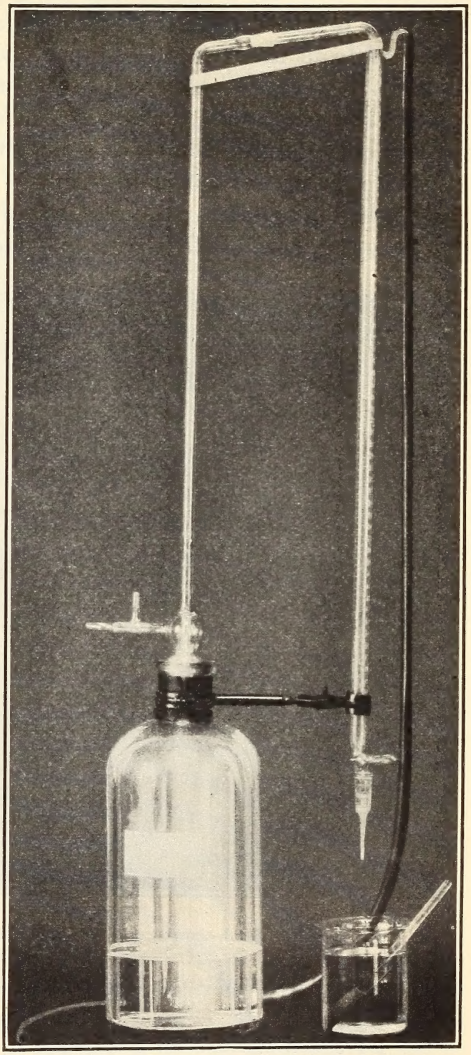


FIG. 5.—Squibb's automatic 50 c. c. burette.

the 95 per cent alcohol in any tall glass container, preferably a cylinder, and add water little by little until the hydrometer reads 0.86. Be careful to mix thoroughly after each addition of water.

(2) Standard alkali solution: Hundredth normal potassium hydroxid (KOH) solution has been found to be the solution best adapted for making this determination, but hundredth normal sodium hydroxid (NaOH) solution will be found satisfactory if potassium hydroxid is not obtainable. The standard alkali solution should be prepared from the fused KOH or NaOH sticks, purified by alcohol, or bought ready for use from a dealer in fine chemicals, as the one making the test desires. The solution is apt to deteriorate on standing for any considerable length of time, and for that reason it is best to buy or make up in small quantities.

(3) Phenolphthalein: A solution of phenolphthalein containing one gram of phenolphthalein in 300 c. c. of alcohol has been found to

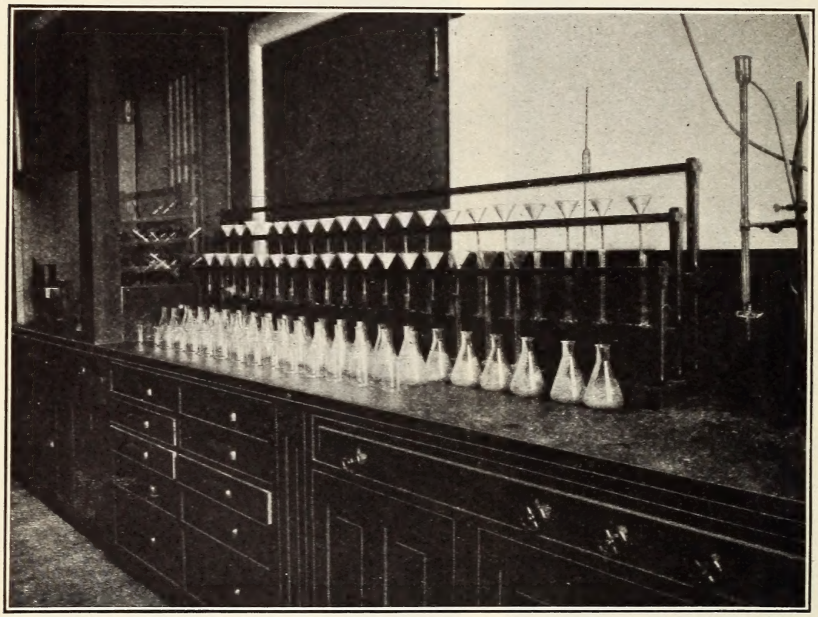


FIG. 6.—Filter stand, showing arrangement of funnels, graduates, flasks, and beakers.

be the most satisfactory indicator. Be careful to mix the solution thoroughly.

(4) Distilled water.

DEGREE OF ACIDITY OF CORN.

CORN SELECTED FOR SEED.

Table I shows the degree of acidity and the percentage of germination of corn selected for seed. The samples from the crop of 1912 represent Illinois corn selected by individual farmers. The samples from the crops preceding 1912 represent corn selected for seed by various State experiment stations, except that the samples from

Iowa were also selected by individual farmers throughout the State. All samples shown in Table I were tested for acidity and germination in the year 1912. The corn at the time of analysis was apparently of first-class quality and in excellent condition, although, as the results of the germination show, some of the samples were unfit for seed.

Analyses of approximately 10,000 samples of corn in this investigation showed a range in degree of acidity from 9 to over 100 c. c. In consideration of this wide range, Table I illustrates the uniform low degree of acidity found in corn selected for seed. Table I shows

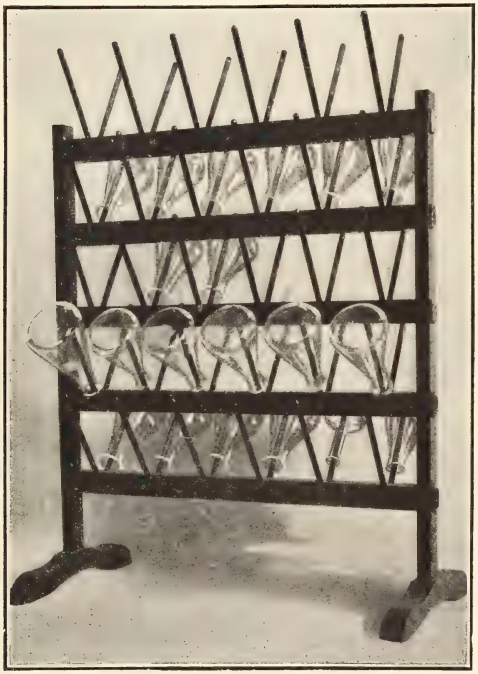


FIG. 7.—Drain stand.

further that, if properly harvested and carefully stored, corn can be kept for several years without suffering any great loss of viability or increasing abnormally in degree of acidity. Although this investigation shows that the degree of acidity is not an absolute criterion of the viability of corn, the results obtained firmly establish the direct relation of the degree of acidity to the percentage of germination.

A degree of acidity of 18 c. c. or below is evidence of a high percentage of germination, and the lower the degree of acidity is found to be the stronger is the evidence of high germinative power or strong viability in the seed.

TABLE I.—*Acidity and germination of corn selected for seed.*

Crop year and laboratory No.	Grown in State of—	Acidity.	Germination.	Crop year and laboratory No.	Grown in State of—	Acidity.	Germination.
Crop of 1906:		*C. c.*	*Per ct.*	Crop of 1912:		*C. c.*	*Per ct.*
38293 C...	Indiana	15.1	96	71990 W..	Illinois	14.6	95
Crop of 1908:				71991 W..	do	18.4	97
38133 C...	Ohio	20.5	96	71992 W..	do	15.0	100
38137 C...	Minnesota	21.5	100	71993 W..	do	15.8	94
Crop of 1909:				71994 W..	do	17.2	97
38445 C...	Missouri	23.8	56	72150 W..	do	15.0	99
38134 C...	Ohio	21.9	92	72151 W..	do	16.6	90
38138 C...	Minnesota	17.8	82	72152 W..	do	15.0	100
Crop of 1910:				72153 W..	do	15.0	100
39147 C...	Kansas	18.5	88	72154 W..	do	15.0	99
39148 C...	do	17.5	100	72155 W..	do	17.2	100
39149 C...	do	16.6	98	72156 W..	do	17.0	92
39150 C...	do	15.5	98	72157 W..	do	16.2	100
38446 C...	Missouri	23.2	42	72158 W..	do	16.6	97
38135 C...	Ohio	19.4	98	72159 W..	do	18.2	100
38139 C...	Minnesota	20.4	100	72160 W..	do	13.8	100
38294 C...	Indiana	22.5	[1] 34	72161 W..	do	16.6	96
38295 C...	do	20.6	88	72162 W..	do	14.8	98
38088 C...	Wisconsin	19.5	98	72163 W..	do	17.4	100
38090 C...	do	21.0	98	71563 W..	do	19.0	91
Crop of 1911:				71564 W..	do	16.8	99
38444 C...	Missouri	16.6	100	71565 W..	do	18.8	100
38447 C...	do	13.6	98	71566 W..	do	16.6	100
38136 C...	Ohio	18.2	96	71567 W..	do	17.4	100
38132 C...	Minnesota	19.5	98	71568 W..	do	16.4	100
38296 C...	Indiana	18.1	94	71569 W..	do	16.2	96
38087 C...	Wisconsin	18.7	100	71570 W..	do	18.4	100
38089 C...	do	15.9	100	71571 W..	do	16.4	99
38372 C...	Iowa	18.0	94	71572 W..	do	20.6	96
38373 C...	do	18.0	100	71573 W..	do	18.6	100
38374 C...	do	16.8	100	71574 W..	do	17.0	98
38375 C...	do	19.6	100	71575 W..	do	18.0	100
38376 C...	do	18.6	88	71754 W..	do	16.4	95
38377 C...	do	18.6	82	71755 W..	do	16.2	100
38378 C...	do	20.2	17	71756 W..	do	18.0	100
38379 C...	do	15.8	90	71757 W..	do	17.8	95
38380 C...	do	17.9	94	71758 W..	do	16.4	98
38381 C...	do	17.4	98	71759 W..	do	15.2	98
Crop of 1912:				71760 W..	do	15.6	100
71558 W..	Illinois	19.0	99	71799 W..	do	16.2	98
71559 W..	do	16.8	100	71800 W..	do	18.0	100
71560 W..	do	17.4	100	71801 W..	do	16.6	100
71561 W..	do	18.6	92	71802 W..	do	16.8	100
71562 W..	do	17.4	99	71803 W..	do	17.0	94
71820 W..	do	16.0	100	71804 W..	do	16.0	99
71913 W..	do	17.4	97	71805 W..	do	18.8	100
71914 W..	do	14.2	98	71806 W..	do	15.8	100
71915 W..	do	14.2	100	71807 W..	do	16.0	100
71916 W..	do	14.2	99	71808 W..	do	15.6	100
71917 W..	do	17.8	100	71809 W..	do	19.6	97
71918 W..	do	15.0	97	71810 W..	do	18.6	99
71919 W..	do	16.6	96	71811 W..	do	18.0	96
71920 W..	do	14.2	100	71812 W..	do	18.0	96
71921 W..	do	14.6	97	71813 W..	do	15.8	98
71922 W..	do	18.6	99	71814 W..	do	17.4	99
71979 W..	do	17.8	100	71815 W..	do	15.8	100
71980 W..	do	17.8	98	71816 W..	do	17.4	79
71981 W..	do	16 4	96	71817 W..	do	15.6	100
71982 W..	do	19 0	96	71818 W..	do	17.6	82
71983 W..	do	17 6	96	71819 W..	do	15.0	99
71984 W..	do	19.0	99	72186 W..	do	16.0	95
71985 W..	do	19.6	96	72187 W..	do	16.6	93
71986 W..	do	17.0	99	72188 W..	do	15.0	98
71987 W..	do	16.4	98	72189 W..	do	15.8	98
71988 W..	do	15.6	99	72195 W..	do	13.6	95
71989 W..	do	18.4	100	72196 W..	do	16.0	97

[1] Weak.

Table II shows a summary of the analyses of 127 samples of corn selected for seed, giving the average acidity and average germination for each year and all years combined. Attention is called to the fact of the low average degree of acidity of 17.2 c. c. in connection with

the correspondingly high average percentage of germination 95.2. The results shown in this table were all determined in 1912.

TABLE II.—*Average acidity and average germination of corn selected for seed from the crops of six different years.*

Crop of—	Number of samples.	Average acidity.	Average germination.
		C. c.	*Per cent.*
1906	1	15.1	96
1908	2	21.0	98
1909	3	21.2	77
1910	11	19.5	86
1911	17	17.7	91
1912	93	16.7	98
Total	127		
General average (all crops)		17.2	95.2

CORN ON THE FARM.

Table III shows a comparison of the analyses of corn at the time of harvest and at different periods of storage both in the crib and in shocks. The shocks were well put up and afforded good protection to the corn. Attention is invited to the low degree of acidity and high moisture content of the corn on October 1 and to the decrease in moisture on the succeeding dates. It will be noted that on May 1 the corn was still low in degree of acidity, after having lost its excessive moisture during storage through the winter on the farm.

TABLE III.—*Acidity and moisture of corn kept from October 1, 1910, to May 1, 1911, inclusive, in shocks and in crib under country conditions at the Maryland station, College Park, Md.*

Sample.	Item of comparison.	Dates of sampling. Oct. 1, 1910.	Feb. 13, 1911.	May 1, 1911.
Composite inside of shocks	Moisture ..... per cent.	24.9	16.0	14.6
	Acidity ..... c. c.	11.0	17.0	17.0
Composite outside of shocks	Moisture ..... per cent.	24.9	16.0	13.3
	Acidity ..... c. c.	13.5	19.0	17.0
Composite of shocks	Moisture ..... per cent.	23.4	16.0	13.9
	Acidity ..... c. c.	12.6	18.0	17.0
Composite of crib	Moisture ..... per cent.	(1)	16.9	14.0
	Acidity ..... c. c.	(1)	17.5	15.0

[1] No corn in crib.

Attention is called in Table IV to a comparison of the keeping qualities of corn stored in different cribs used throughout the Middle West. Corn was examined in January, February, March, April, and May, 1913, and it was found that very little change had taken place while stored in any of the several cribs. On the whole, the corn was

in very good condition and the degree of acidity of the corn stored on the farm through the winter was uniformly low.

TABLE IV.—*Acidity and germination of corn stored over winter on Illinois farms in cribs of different type.*

Type of covered crib.	Location.	Item of comparison.	Dates of sampling, 1913.				
			January.	February.	March.	April.	May.
Rail crib	Turpin, Ill.	Acidity....c. c.	18.6	15.0	15.4	15.4	[1]
		Germination....per cent.	96.0	100.0	98.0	99.0	
Single crib	Cerro Gordo, Ill.	Acidity....c. c.	14.0	13.4	14.6	12.6	13.4
		Germination....per cent.	98.0	97.0	97.0	98.0	90.0
Double crib	Long Creek, Ill	Acidity....c. c.	18.4	15.2	16.8	15.3	15.4
		Germination....per cent.	98.0	96.0	94.0	85.0	90.0

[1] Crib shelled out.

Ears of corn were collected representing all parts of several cribs of corn in Illinois, and a uniformly low degree of acidity was found throughout the individual ears, as shown in Table V. In the sampling of these cribs, care was taken to secure ears which would represent the corn in the crib as a whole.

TABLE V.—*Average and range in degree of acidity of individual ears of corn sampled from farm cribs at Turpin, Long Creek, and Cerro Gordo, Ill.*

Total number of ears.	Acidity (c. c.).			Number of ears with acidity—			
	Average.	Minimum.	Maximum.	Below 20 c. c.	Between 20.1 and 25 c. c.	Between 25.1 and 30 c. c.	Above 30 c. c.
144	17.0	9.8	31.8	120	21	2	1

CORN IN COUNTRY, TERMINAL, AND EUROPEAN MARKETS.

Acidity determinations were made of several thousand samples representing corn selected for seed, country elevator receipts and shipments, terminal-market receipts, and corn as loaded at seaboard for export and as discharged at foreign ports. Corn selected for seed was taken as that best representing the average condition of corn on the farm. Table VI shows that there is a steady increase in the acidity as the corn passes through the different grain centers from the farm until it has reached a foreign port. While the average of all the corn except that which was received at foreign ports is below 22 c. c. in acidity, it will be seen from the range given in the right-hand column that there were some samples in all cases that could not be classed as sound corn, and on the other hand, while the corn as received at foreign ports had an average acidity of 30.4 c. c., indi-

cating an inferior quality, it will be seen from the range that some arrived in practically as good condition as when it left the farm. This table represents an average of 7,124 samples.

TABLE VI.—*Average acidity and range in acidity of samples representing corn selected for seed, corn received at and shipped from country elevators, corn received at terminal markets, and corn as loaded at seaboard for export and as discharged at foreign ports.*

Kind of corn.	Number of samples.	Acidity (c. c.).	
		Average.	Range.
Corn selected for seed	127	17.2	13.6 to 23.8
Country elevator receipts and shipments	197	19.4	14.5 to 50.8
Terminal-market receipts	5,174	20.4	11.7 to 66.4
Loaded at seaboard for export	1,098	20.2	12.4 to 32.0
Discharged at foreign ports	528	30.4	16.0 to 110.8

A comparison was made of the graded and the rejected and sample-grade receipts as they were received at Baltimore, New Orleans, Chicago, and Kansas City, and it was found that the average acidity of the rejected and sample-grade corn as shown in Table VII was much higher in all markets than the acidity of the graded receipts. This table represents a total of 5,174 cars.

TABLE VII.—*General average degree of acidity of corn receipts at four of the principal terminal markets, showing the relation of the degree of acidity of the graded receipts to the degree of acidity of the rejected receipts and sample grade.*

Market.	All receipts.		Graded receipts.		Rejected and sample grade receipts.	
	Number of samples.	Average acidity.	Number of samples.	Average acidity.	Number of samples.	Average acidity.
		C. c.		C. c.		C. c.
Baltimore	1,737	20.6	1,659	20.3	78	26.8
New Orleans	755	22.9	573	20.6	182	30.6
Chicago	2,450	19.7	2,208	19.2	242	23.2
Kansas City	232	18.7	220	18.1	12	29.2

RELATION OF THE ACIDITY OF CORN TO CERTAIN CRITERIA OF SOUNDNESS AND QUALITY.

In order to determine whether or not the amount of acid found in corn may be considered a factor in judging its quality and soundness, the results of the acid test must be compared with all well-established and generally acknowledged criteria of soundness and quality.

Viability (or germinative power), temperature, and percentage of sound and damaged kernels as determined by mechanical analysis are criteria of the soundness and quality of corn.

Corn having attained a temperature higher than normal, through heating in storage or transit, is conceded to be unsound and of poorer

quality than corn which has never been subjected to a temperature above normal.

Corn showing upon mechanical analysis a high percentage of sound kernels and a low percentage of damaged kernels must be conceded to more closely approximate sound corn and be of better quality than

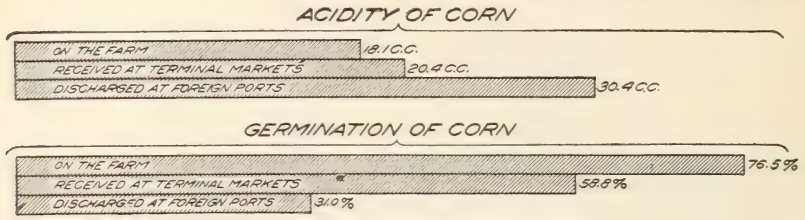


FIG. 8.—Graphic comparison of the degree of acidity and the percentage of germination of corn (1) as found on the farm, (2) as received at terminal markets, and (3) as discharged at foreign ports.

corn showing a lower percentage of sound kernels and higher percentage of damaged kernels.

VIABILITY, OR PERCENTAGE OF GERMINATION.

The results of the investigations show in a general way that the degree of acidity of corn increases as the viability, or percentage of germination, decreases.

Figure 8 is a graphic comparison of the degree of acidity and the percentage of germination of corn as found on the farm, as received at terminal markets, and as discharged at foreign ports.

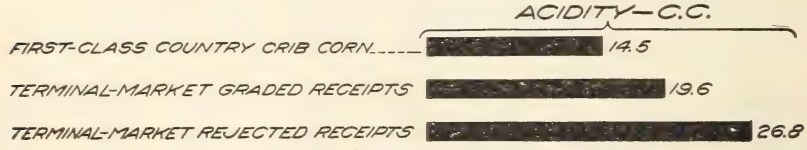


FIG. 9.—Graphic comparison of the acidity of first-class country crib corn with the acidity of terminal-market graded and rejected receipts.

Figure 9 further summarizes the relation of the degree of acidity found in corn on the farm to the acidity found in corn arriving at terminal markets.

In figure 10 the samples represent corn saved for seed in several States and of various crop years. These samples were found to be uniformly low in degree of acidity. In the figure will be noted an acidity sound-corn line at 22 c. c. on the acidity scale. The investigation shows that this line most closely approximates the maximum degree of acidity found in corn which was sound and of good quality. It will be seen that three samples of corn selected for seed exceeded

an acidity of 22 c. c., but it will be seen also that these three samples were exceptionally low in percentage of germination. A fourth sample very low in percentage of germination did not exceed an acidity of 22 c. c. The agent or agencies which destroyed the germinative power of this corn did not cause abnormal increase in degree of acidity. This is contrary to the general rule, because agencies which destroy germinative power are generally the same agencies which cause abnormal acidity. It is mainly through deterioration of the germ that the degree of acidity is increased, as shown in figures 32 and 33 (p. 44).

Table VIII summarizes the relationship of low germinative power to high acidity. Germination tests were made in connection with

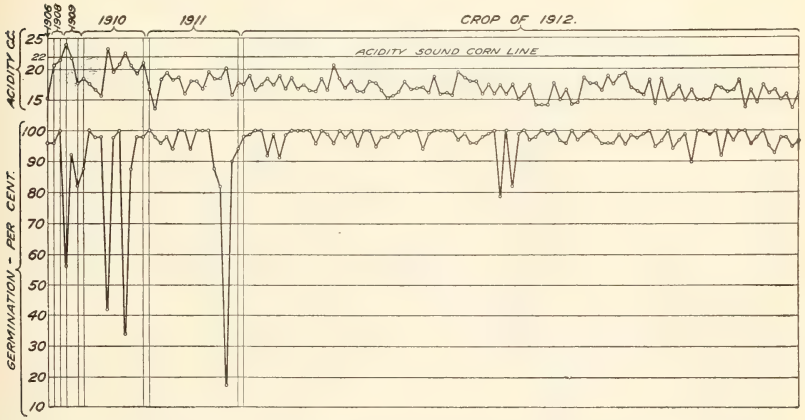


FIG. 10.—Curves showing the uniformly low degree of acidity in corn selected for seed in which there is a high percentage of germination.

acidity tests on all samples handled in this investigation. The samples in this table represent the widest possible range in quality and condition of corn, from first-class country crib corn in excellent condition through various conditions and stages of deterioration as found in corn shipped from country stations and arriving at terminal markets and European ports. The samples are grouped according to their source. The average degree of acidity of samples in each group which showed a percentage of germination less than 20 is compared with the average degree of acidity of samples which showed a percentage of germination ranging from 21 to 40, 41 to 60, 61 to 80, and 81 to 100. The table shows that corn with a low germinative power is higher in degree of acidity than corn of high germinative power, irrespective of the source of the sample.

TABLE VIII.—*Samples representing corn on the farm, at country shipping points, at terminal markets, and at foreign ports, showing the increase in degree of acidity in direct proportion to the decrease in percentage of germination.*

Source of samples.	Item of comparison.	Samples which showed a range in the percentage of germination from—				
		0 to 20	21 to 40	41 to 60	61 to 80	81 to 100
Individual ears from farm cribs.	Number of samples		2	2	9	131
	Average acidity....c.c.		29.9	20.6	18.2	16.6
Country elevator receipts and shipments.	Number of samples	7	28	60	86	21
	Average acidity....c.c.	29.8	21.1	18.9	19.3	19.6
Terminal market receipts.	Number of samples	598	657	968	1,830	1,058
	Average acidity....c.c.	26.6	21.8	19.6	19.3	18.6
Corn discharged at foreign ports.	Number of samples	167	129	76	74	9
	Average acidity....c.c.	39.9	25.5	25.5	21.5	18.0

EFFECT OF POOR CARS ON THE CONDITION OF CORN.

Corn often arrives at terminal markets in cars with leaky roofs, and not infrequently the grain directly under the leaky part becomes

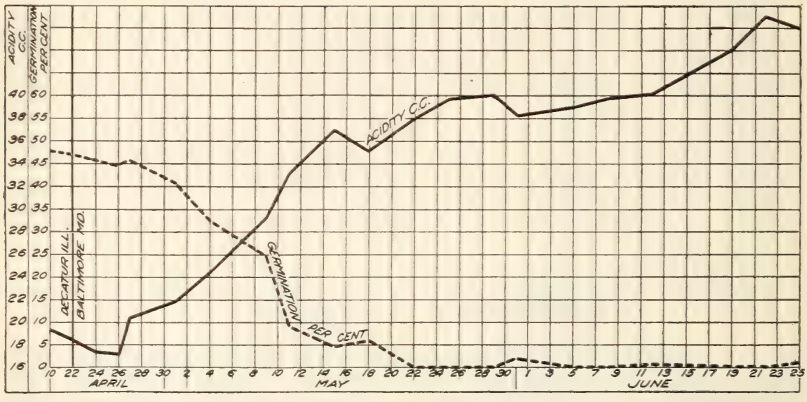


FIG. 11.—Curves showing the increase in degree of acidity and the decrease in percentage of germination through advancing stages of deterioration in a car of corn.

wet and reaches advanced stages of deterioration while the greater part of the corn in the car remains sound and in good condition.

Table IX shows the results of acidity and germination tests made on samples taken from both the good and bad parts of such cars.

TABLE IX.—*Comparison of the average acidity and the average germination of corn sampled in the good and the bad parts of cars received at a terminal market.*[1]

Source of samples.	Average acidity.	Average germination.
	C.c.	*Per cent.*
Good part of car	18.6	67.7
Bad part of car	23.4	49.0

[1] These results represent an average of 73 cars.

Figure 11 shows the direct and the proportional increase in the degree of acidity with the decrease in percentage of germination of samples taken from a car of corn which was shipped from Decatur, Ill., to Baltimore, Md., and allowed to stand on the track in Baltimore until it was in an advanced stage of deterioration.

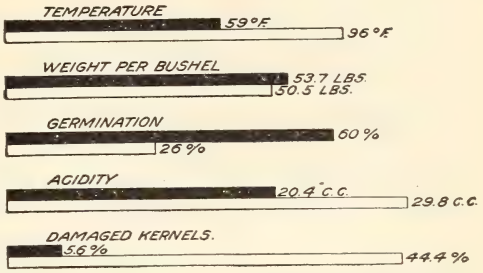


FIG. 12.—Graphic comparison of the average condition of a cargo of corn at the time of loading at a United States seaport compared with its average condition at the time of discharge at a European port, showing the effect of temperature through ocean transportation on various factors which determine the soundness and quality.

RELATION TO TEMPERATURE.

Figure 12 shows the average condition of a cargo of corn loaded at a United States seaport compared with the average condition at the time of discharge of the cargo at a European port. The degree of acidity varies directly with the quality and soundness of the corn, as is indicated by the variation of the other factors graphically shown.

In figure 13 reference is again made to a car of corn shipped from Decatur, Ill., to Baltimore, Md. At the time of its arrival at Baltimore the corn contained an average moisture percentage of 18.60. Four days after its arrival at Baltimore the temperature began to

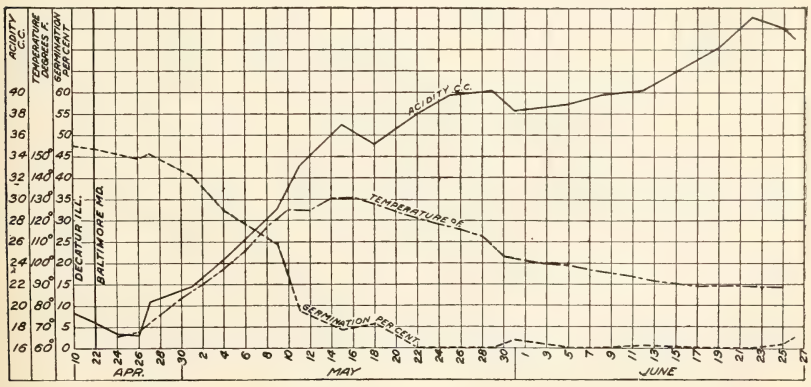


FIG. 13.—Curves showing the effect of temperature on the degree of acidity and the percentage of germination of a car of corn which was left on the railway track through advancing stages of deterioration.

increase rapidly, and with the increase in temperature there was a proportional increase in degree of acidity and a corresponding decrease in the percentage of germination.

Figure 14 shows the relation of the degree of acidity to the condition of corn before and after a storage experiment in a large elevator

bin at a terminal market. During the course of the experiment the corn was allowed to go out of condition and underwent considerable deterioration. The degree of acidity is shown as a factor in comparison with other factors which determine the quality and soundness of corn.

Corn under certain conditions may attain a temperature of 100° F. or more before it becomes discolored or shows to the eye any effect of damage by heat. Table X shows the effect of the increase of temperature upon the degree of acidity, percentage of germination, and percentage of sound kernels as found in samples having undergone ocean transportation. The samples were taken at European ports at the time the vessels were unloaded. Nine cargoes are represented. The corn at the time of loading was cool, the greatest bulk of it being below 50° F. Through ocean transportation covering a period ranging from 14 to 30 or 35 days[1] a large part of the corn attained a temperature greater than it had at the time of loading. This increase varied from one or two to over a hundred degrees in the case of the badly damaged portions of the cargoes. In the table the degree of acidity and the percentages of germination and of sound kernels represent the average of all samples which showed temperatures below 50° F., between 51° and 60°, between 61° and 70°, between 71° and 80°, between 81° and 90°, between 91° and 100°, and above 100°, respectively, at the time of discharge of the cargoes. Samples which attained a temperature of 71° or more showed marked evidence of deterioration, and the higher the temperature the more advanced the stage of deterioration and the higher the degree of acidity.

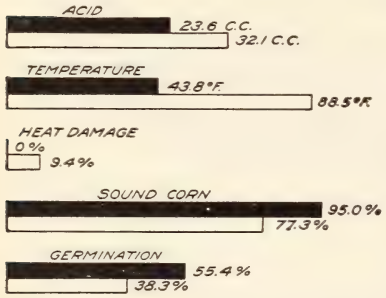


FIG. 14.—Graphic comparison of the condition of corn at the time an elevator storage bin was filled and at the time the bin was emptied, showing the degree of acidity as a factor in comparison with other factors which determine quality and soundness.

TABLE X.—*Degree of acidity, percentage of germination, and percentage of sound kernels of samples representing 9 cargoes of exported corn, showing the effect of the increase of temperature.*

Basis of comparison.	Temperature of samples at time of discharge (° F.).						
	Below 50°.	51° to 60°.	61° to 70°.	71° to 80°.	81° to 90°.	91° to 100°.	Above 100°.
Number of samples	106	65	70	44	29	20	109
Degree of acidity.....c. c..	21.0	24.4	26.8	31.9	33.5	33.7	42.5
Germination.....per cent..	50.2	39.4	42.1	36.0	21.7	18.8	4.2
Sound kernels as determined by mechanical analysis, per cent.	88.38	84.4	81.65	71.68	60.73	50.94	14.10

[1] In the case of one vessel a period of 50 days elapsed from the time of loading until the time of discharge.

RELATION TO THE PERCENTAGE OF SOUND KERNELS.

In Table XI the degree of acidity as found in approximately 2,400 samples is compared in a general way with the percentage of sound kernels found in the same samples by mechanical analysis. The results in section A of the table represent samples from all grades of car receipts at a principal terminal market from December, 1911, to November, 1912, inclusive. The samples represented in section B of the table were taken at the time the cargoes were discharged at European ports from nine vessels loaded at the United States seaboard.

TABLE XI.—*Comparison of the degree of acidity of samples of corn which were found upon mechanical analysis to contain a low percentage of sound kernels with the degree of acidity of samples which contained higher percentages of sound kernels.*

A.—REPRESENTATIVE OF ALL GRADES OF CAR RECEIPTS AT A TERMINAL MARKET.

Basis of comparison.	Sound kernels (per cent).					
	Less than 50.	51 to 60.	61 to 70.	71 to 80.	81 to 90.	91 to 100.
Number of samples	28	13	26	91	456	1,467
Average acidity.....c. c..	34.8	32.0	27.4	25.9	22.5	18.6

B.—REPRESENTATIVE OF NINE CARGOES DISCHARGED AT EUROPEAN PORTS.

Number of samples	58	18	17	25	91	92
Average acidity .....c. c..	40.9	31.1	32 9	28.8	24 4	21 2
Average germination .....per cent..	5.3	18.6	29.8	38.8	41.0	55.9

RELATION TO THE PERCENTAGE OF DAMAGED KERNELS.

In figure 15 is shown the relation of the percentage of damaged kernels to the degree of acidity found in samples of corn of all grades, representing 2,454 cars received at a principal terminal market (C) from December, 1911, to May, 1913, inclusive. These cars of corn ranged from 10 to 60 c. c. in degree of acidity. The percentage of cob-rotten kernels and the percentage of heat-damaged kernels, if any, was determined by the mechanical analysis of a representative sample from each car.

It is the purpose of figure 15 to illustrate the general way in which the acidity of corn increases with the amount of damaged kernels as detected by the eye in mechanical analysis. The point at which the curve intersects a perpendicular cross-section line denotes the average percentage of damaged kernels found in the samples, which ranged in degree of acidity as designated at the top of the perpendicular cross-section line. The average percentage of damaged kernels is shown at the left. The curve designated "cob rot" (solid line) represents the percentage of kernels damaged by agencies other than

heat. The curve designated "cob rot plus heat damage" (broken line) represents the percentage of the total of the damaged kernels.

The curves show that the samples which were found by analysis to have a large percentage of damaged kernels were also found to have a high degree of acidity. It is shown further that the degree of acidity varies directly with the percentage of damaged kernels and that the presence of heat-damaged kernels in any large amount

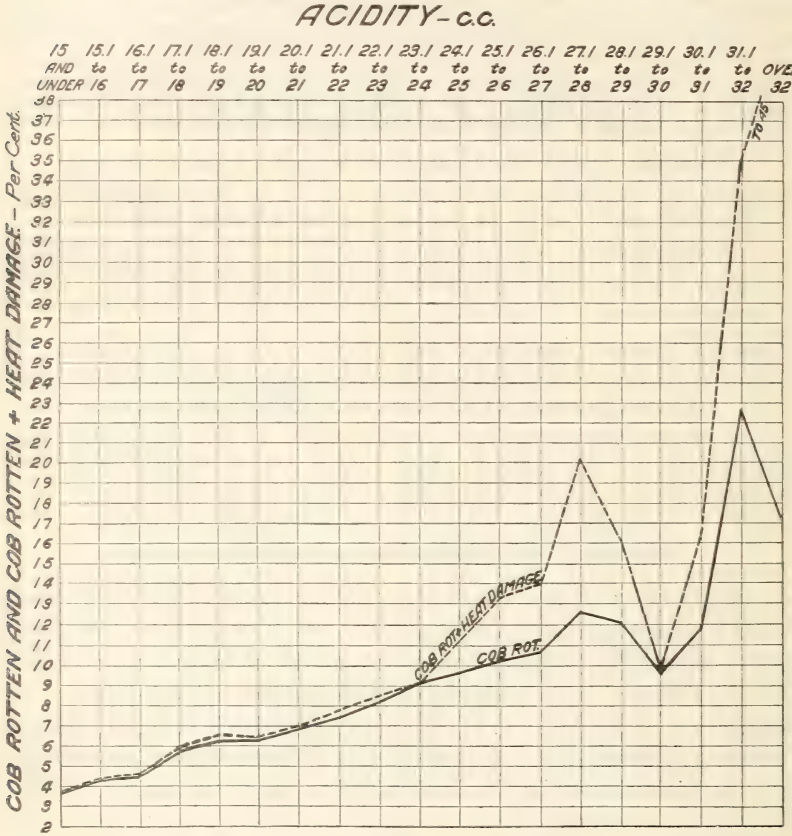


FIG. 15.—Curves showing the relation of damaged kernels to the degree of acidity found in samples of corn (all grades) representing 2,454 cars received at a principal terminal market (C) from December, 1911, to May, 1913, inclusive.

greatly increases the degree of acidity. When the percentage of heat-damaged kernels was small, the degree of acidity was only slightly increased. A break occurs in the continuity of the curves representing the percentages of damaged kernels at acidity ranges between 27.1 and 31 c. c. This break shows that a number of the samples, although having a slightly higher degree of acidity than certain other samples, contained a smaller percentage of damaged

kernels. The difference, however, is small, being only 2.5 per cent, and this evidence should in no way discredit the merits of the acid test. It must be remembered that, theoretically, the degree of acidity of corn is a measure not only of the amount or quantity of damage but that it is also a measure of the quality or degree of damage in any given sample. Hence, it can be readily understood how a sample containing 10 per cent of damaged kernels might have a higher degree of acidity than a sample containing 15 per cent of damaged kernels, provided the degree of damage or the extent to which the kernels were damaged is taken into consideration. This factor of degree or state of damage, or stage of deterioration, while

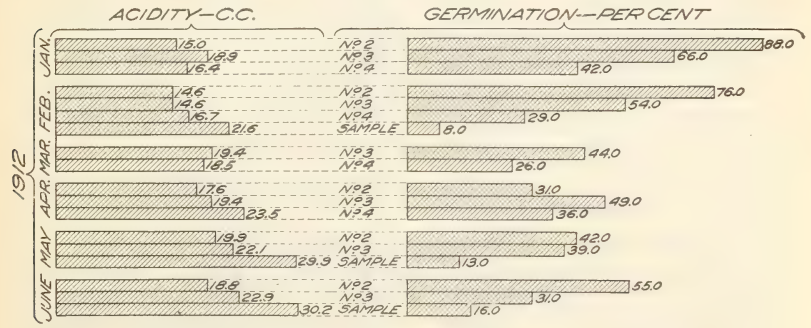


FIG. 16.—Graphic comparison of the average degree of acidity and the average percentage of germination for each commercial grade of corn received at a terminal market (A), by months, from January to June, 1912, inclusive.

immeasurable by the eye in any standard or definite way, is readily determined by the acidity test.

RELATION OF ACIDITY AND GERMINATION OF CORN TO COMMERCIAL GRADING AT TERMINAL MARKETS.

The purpose in presenting figures 16, 17, 18, 19*a*, and 19*b* is to correlate the average degree of acidity and the average percentage of germination of corn with the commercial grading at terminal markets by months. Attention is called to the increase in the degree of acidity and the decrease in the percentage of germination from the high to the lower grades. Attention is also called to the decrease in degree of acidity and the marked increase in the percentage of germination upon the arrival of the new crop in November, as shown in figures 17, 18, 19*a*, and 19*b*.

ACIDITY OF CORN AS A FACTOR IN COMMERCIAL GRADING.

ACIDITY OF COMMERCIAL GRADES.

Corn arriving at a terminal market is graded or classified according to its condition and quality. In this connection the words "condition" and "quality" are more or less synonymous. It is generally

understood, however, in commercial grading that "condition of corn" refers to freedom from or presence of dirt, cob, broken ker-

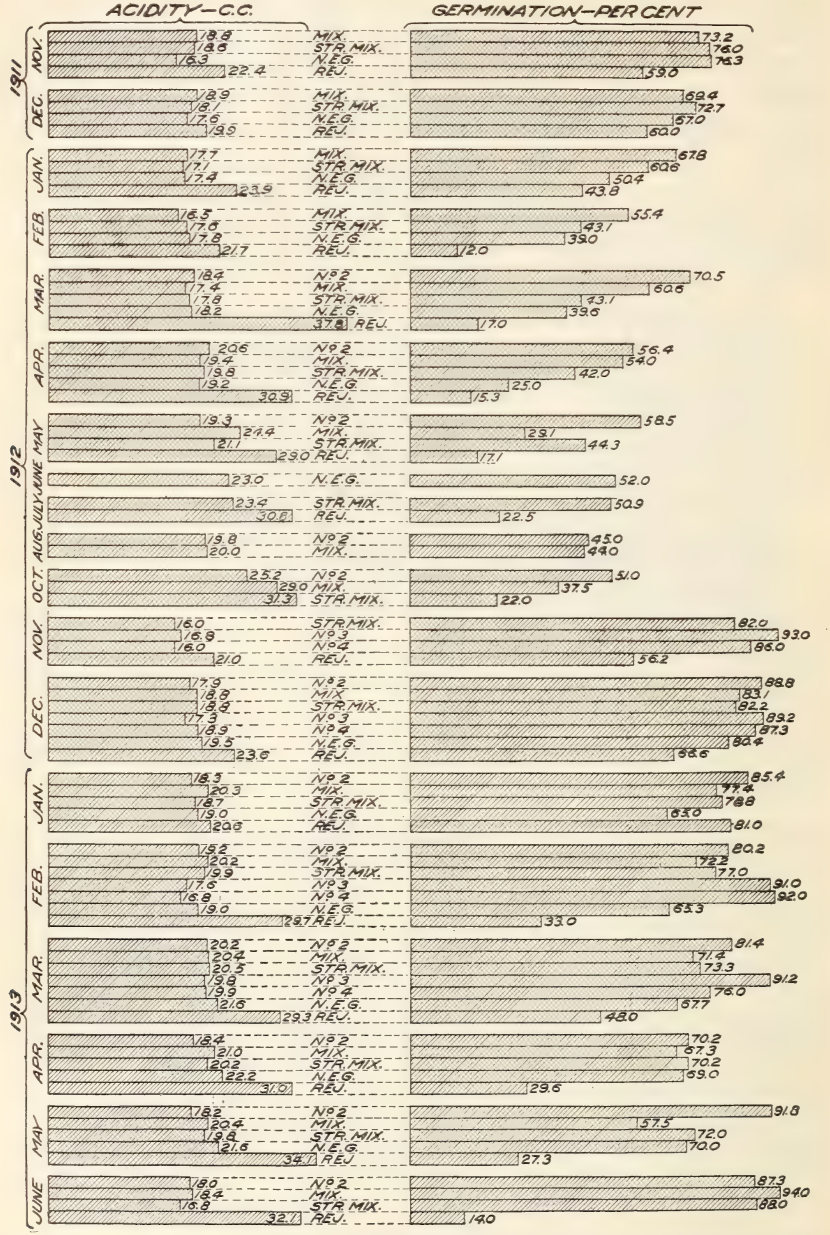


FIG. 17.—Graphic comparison of the average degree of acidity and the average percentage of germination for each commercial grade of corn received at a terminal market (B), by months, from November, 1911, to June, 1913, inclusive.

nels, other grains, unnatural odors, and excessive percentage of moisture—as corn is spoken of as being clean or dirty; mixed with

oats or wheat; musty, sour, or sweet; damp, wet, or dry. The word "quality," then, in connection with grading of corn, must refer to soundness, meaning freedom from injury, defect, or decay, i. e., normally perfect of its kind.

Of the factors affecting the condition of corn, viz, dirt, cob, broken kernels, other grains, unnatural odor, and moisture, all with the

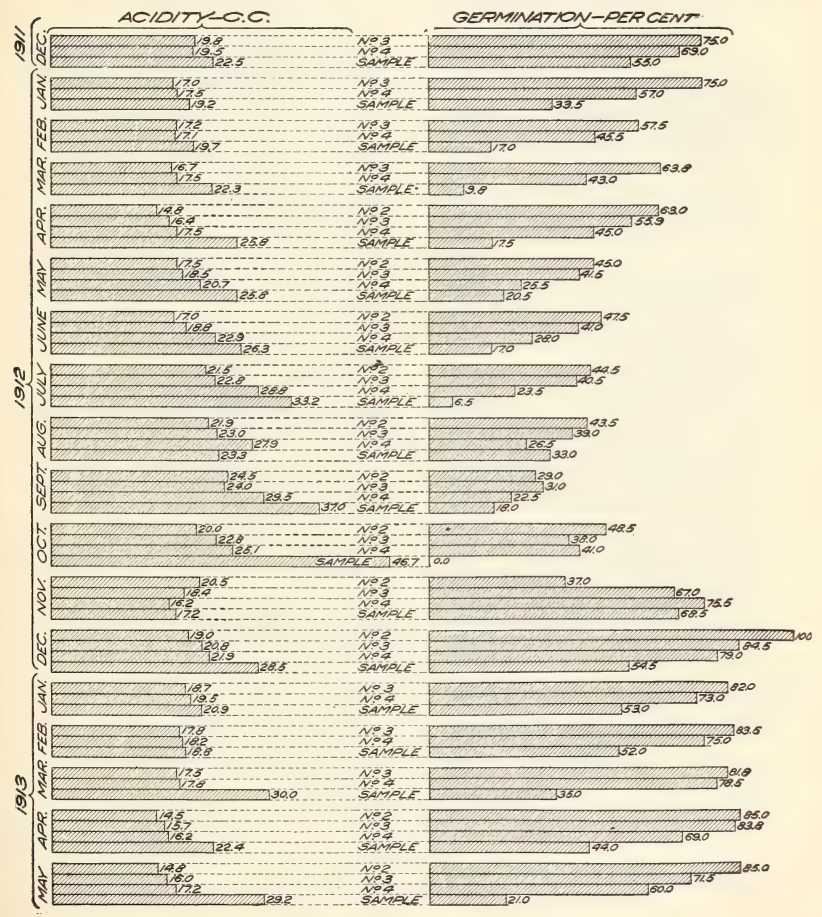


FIG. 18.—Graphic comparison of the average degree of acidity and the average percentage of germination for each commercial grade of corn received at a terminal market (C), by months, from December, 1911, to May, 1913, inclusive.

exception of odor can be definitely ascertained by practical and quantitative methods. The exact percentage of dirt, cob, broken kernels, and other grains can be readily determined by mechanical separations; the percentage of moisture can be as readily determined by the use of a moisture tester.[1]

[1] Duvel, J. W. T. A moisture tester for grain and other substances and how to use it. U. S. Department of Agriculture, Bureau of Plant Industry Circular 72, 15 p., 13 fig., 1910.

Heretofore in commercial grading, corn has been considered out of condition because of unnatural odor only when the odor is sufficiently pronounced to be readily detected by the sense of smell, which varies with different individuals and even with the same individual under different conditions.

In the grading of corn from the standpoint of quality or soundness, however, the methods are entirely arbitrary, inasmuch as there is

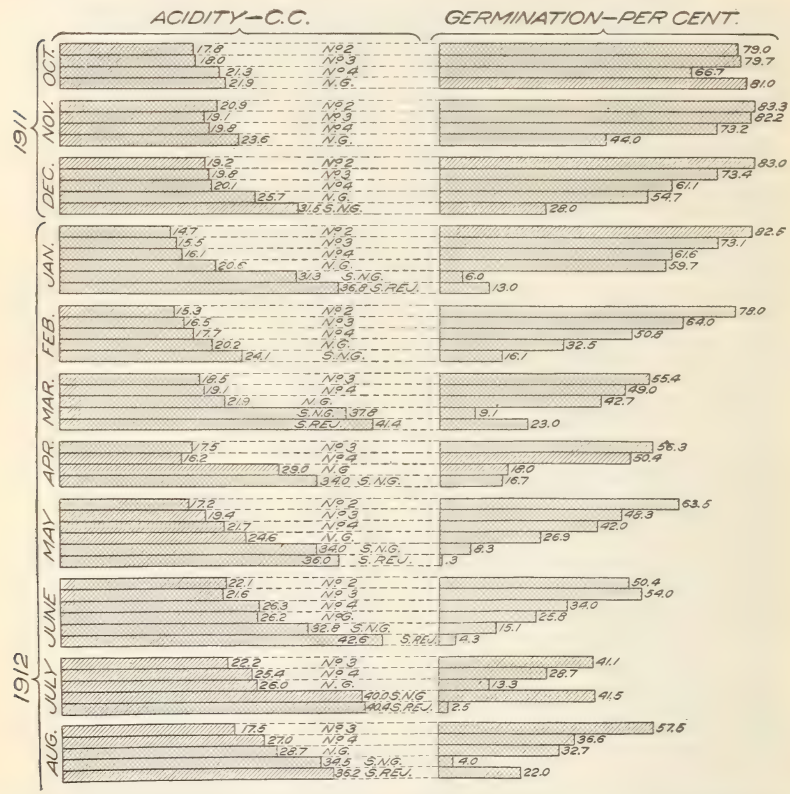


FIG. 19a.—Graphic comparison of the average degree of acidity and the average percentage of germination for each commercial grade of corn received at a terminal market (D), by months, from October, 1911, to August, 1912, inclusive.

always considerable question as to just what constitutes cob-rotten, decayed, or otherwise damaged and defective kernels in any given sample which may be under inspection.

It is the purpose of this section of this report to show the relation of degree of acidity in a detailed way to acknowledged criteria of soundness and quality of corn and to call to the attention of the grain trade and those of the general public who may be interested

the possibilities of the acid test as an additional criterion in determining soundness and quality of corn from the standpoint of commercial grading.

The samples shown in Tables XII to XIX and figures 20 to 31 and 33 were graded by the Illinois State Grain Inspection Department

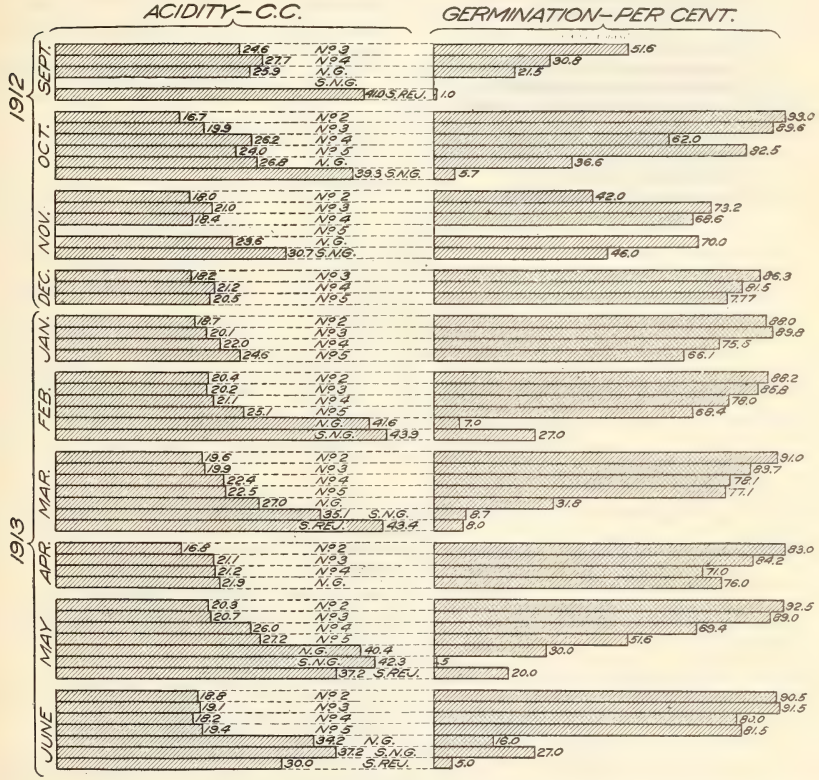


FIG. 19b.—Graphic comparison of the average degree of acidity and the average percentage of germination for each commercial grade of corn received at a terminal market (D), by months, from September, 1912, to June, 1913, inclusive.

according to the rules governing the grading of grain in the years 1912 and 1913.

Figure 20 shows the average degree of acidity of Nos. 2, 3, 4, and sample-grade corn as it was graded upon arrival at a principal terminal market (C), representing an average of approximately 2,000 cars received from December, 1911, to December, 1912, inclusive. Very little difference is shown between the grades 2, 3, and 4. This

is due to the fact that the greater part of the corn that graded 3 and 4 was so graded because of excessive moisture, although sound and of quality good enough for No. 2. Figure 20 also shows the average degree of acidity of samples received from April 1, 1912, to October 31, 1912, inclusive. This is the time of the year during which corn arrives at terminal markets in a drier condition and is graded principally from the standpoint of quality and soundness. It will be seen that the degree of acidity increases directly with the lowering of the grades. Figure 20 further shows the average degree of acidity of samples received from January 1, 1913, to May 31, 1913, inclusive. Increase in acidity is shown through the lower grades, and uniformly lower acidity was found in Nos. 2, 3, and 4 corn of the crop of 1912 than was found in samples from the crop of 1911. This comparison by crop years will appeal to those who may recall the far superior quality and condition of the crop of 1912 as it was marketed over that of the crop of 1911.

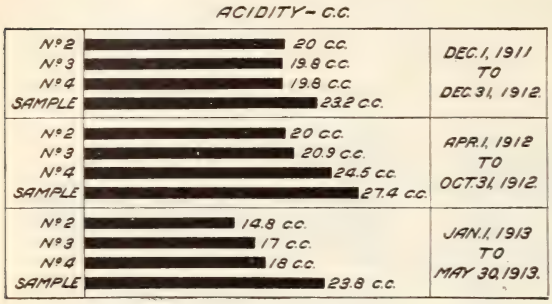


FIG. 20.—Graphic comparison of the average degree of acidity of corn, by grades, as received at a principal terminal market (C) through different seasons: (1) December, 1911, to December, 1912; (2) April, 1912, to October, 1912; (3) January, 1913, to May, 1913.

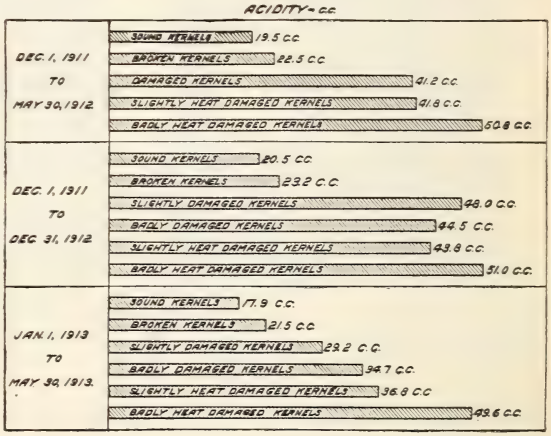

ACIDITY- C.C.
DEC. 1, 1911 TO MAY 30, 1912
SOUND KERNELS 19.5 C.C.
BROKEN KERNELS 22.5 C.C.
DAMAGED KERNELS 41.2 C.C.
SLIGHTLY HEAT DAMAGED KERNELS 41.8 C.C.
BADLY HEAT DAMAGED KERNELS 50.6 C.C.
DEC. 1, 1911 TO DEC. 31, 1912
SOUND KERNELS 20.5 C.C.
BROKEN KERNELS 23.2 C.C.
SLIGHTLY DAMAGED KERNELS 48.0 C.C.
BADLY DAMAGED KERNELS 44.5 C.C.
SLIGHTLY HEAT DAMAGED KERNELS 43.8 C.C.
BADLY HEAT DAMAGED KERNELS 51.0 C.C.
JAN. 1, 1913 TO MAY 30, 1913.
SOUND KERNELS 17.9 C.C.
BROKEN KERNELS 21.5 C.C.
SLIGHTLY DAMAGED KERNELS 29.2 C.C.
BADLY DAMAGED KERNELS 34.7 C.C.
SLIGHTLY HEAT DAMAGED KERNELS 36.8 C.C.
BADLY HEAT DAMAGED KERNELS 43.6 C.C.

FIG. 21.—Graphic comparison of the average degree of acidity of mechanical separations of samples of corn as received at a principal terminal market (C) through different seasons: (1) December, 1911, to May, 1912; (2) December, 1911, to December, 1912; (3) January, 1913, to May, 1913.

ACIDITY OF MECHANICAL SEPARATIONS OF CORN.

Figure 21 shows the average degree of acidity of separations resulting from mechanical analyses of samples of corn representing approximately 3,000 cars received at a terminal market. It also represents the crop of 1911 and the crop of 1912, based on terminal-market receipts from Janu-

ary to May, 1913, inclusive, and represents the general average of both crops combined. By the degree of acidity of the mechanical separations the superior quality and condition of the crop of 1912 is also shown.

In one instance in figure 21 the acidity of the corn designated as "badly damaged" appears somewhat lower than the acidity of the corn designated as "slightly damaged." This is due to the fact that the corn designated as "badly damaged" had so far undergone deterioration as to be typical of rot and decay, which agencies tend to cause a state of alkalinity rather than a state of acidity. At one time, no doubt, before the corn reached that state of rot and decay, the degree of acidity was higher. Rot and decay serve to slightly reduce the maximum degree of acidity which the corn attains in the

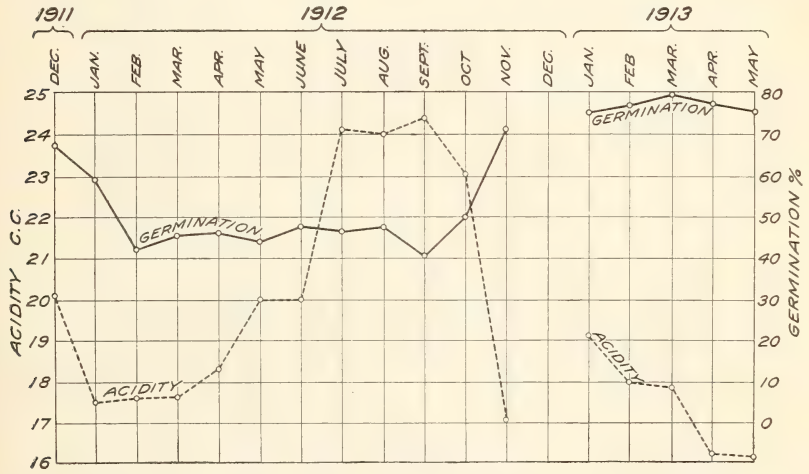


FIG. 22.—Curves showing the monthly average degree of acidity and percentage of germination of corn as received at a principal terminal market (C).

cycle of deterioration, but leaves the degree of acidity sufficiently high to stamp the corn as being wholly unsound.

The general relation of the degree of acidity to the germinative power of corn arriving at a terminal market is shown in figure 22 by curves which represent monthly averages. Attention is called (1) to the marked increase in the degree of acidity and decrease in the percentage of germination starting in the spring with the approach of warm weather and continuing throughout the summer months and again (2) to the very marked decrease in the degree of acidity and increase in the percentage of germination commencing in October, upon the arrival of the new crop. Through germination and acidity the superior quality and condition of the crop of 1912 over the crop of 1911 is again shown by these curves.

RELATION TO GERMINATION AND SOUND KERNELS.

Table XII shows a comparison of the degree of acidity with the percentage of germination and the percentage of sound corn (exclusive of broken kernels). The monthly averages of these three factors are shown for each grade. Examination of this table will also reveal a consistent decrease in the percentage of sound corn and the percentage of germination from the high to the lower grades and a corresponding consistent increase in the degree of acidity.

TABLE XII.—*Relation of the percentage of sound corn, the percentage of germination, and the degree of acidity to the commercial grades, by months, from December, 1911, to May, 1913, inclusive.*

Year and month.	Grade.	Number of samples.			Sound corn.	Germination.	Acidity.
		Sound corn.	Germination.	Acidity.			
1911.					*Per cent.*	*Per cent.*	*C. c.*
December	No. 3	18	16	12	93.8	76.1	19.7
	No. 4	120	112	110	91.2	68.8	19.7
	Sample	38	28	27	89.6	56.3	22.3
1912.							
January	No. 3	68	62	65	91.9	75.3	17.0
	No. 4	145	133	134	90.8	64.4	17.6
	Sample	22	21	21	86.6	39.5	19.2
February	No. 3	34	31	31	91.4	57.9	17.8
	No. 4	123	108	111	91.3	46.7	17.2
	Sample	28	28	28	83.4	18.5	19.9
March	No. 3	59	56	59	90.8	62.0	16.9
	No. 4	112	108	112	90.1	41.1	17.5
	Sample	15	13	14	77.6	9.7	22.3
April	No. 2	6	6	6	91.9	63.3	14.8
	No. 3	43	43	43	89.3	54.8	16.4
	No. 4	99	99	99	87.2	45.5	17.5
	Sample	26	26	26	55.0	17.5	25.9
May	No. 2	39	39	39	89.8	45.4	17.5
	No. 3	117	116	117	86.3	41.3	18.4
	No. 4	78	75	78	78.9	25.1	20.7
	Sample	43	41	43	56.3	20.6	26.1
June	No. 2	38	37	38	90.6	47.6	17.1
	No. 3	116	111	114	88.4	41.3	18.8
	No. 4	67	65	67	82.8	28.2	22.8
	Sample	10	10	10	68.6	17.4	26.3
July	No. 2	59	59	59	90.4	44.4	21.5
	No. 3	66	64	66	87.0	40.5	22.9
	No. 4	34	34	34	80.1	20.8	28.8
	Sample	8	8	8	78.9	6.5	33.2
August	No. 2	34	34	34	90.1	43.7	21.9
	No. 3	65	60	65	88.4	40.2	23.4
	No. 4	34	32	34	82.2	26.8	27.9
	Sample	3	3	3	83.4	33.3	23.2
September	No. 2	20	20	20	91.8	29.2	24.4
	No. 3	41	40	41	88.3	31.2	24.0
	No. 4	35	34	35	81.4	22.6	29.5
	Sample	2	2	2	70.0	18.0	37.0
October	No. 2	17	17	17	92.1	48.5	20.0
	No. 3	61	60	61	87.5	38.0	22.9
	No. 4	18	18	18	81.7	41.1	25.0
	Sample	1	1	1	6.0	0	46.7
November	No. 2	5	5	5	91.0	37.2	20.6
	No. 3	43	43	43	91.1	67.4	18.3
	No. 4	97	97	97	90.8	75.4	16.2
	Sample	34	34	34	86.1	68.4	17.1

TABLE XII.—*Relation of the percentage of sound corn, the percentage of germination, and the degree of acidity to the commercial grades, by months, from December, 1911, to May, 1913, inclusive*—Continued.

Year and month.	Grade.	Number of samples.			Sound corn.	Germination.	Acidity.
		Sound corn.	Germination.	Acidity.			
1912.					*Per cent.*	*Per cent.*	*C. c.*
December	No. 2	1	1	1	96.8	100.0	19.0
	No. 3	25	25	25	91.9	84.6	20.8
	No. 4	34	34	33	90.2	78.7	21.9
	Sample	9	9	9	72.2	54.4	28.5
1913.							
January	No. 3	26	26	24	92.5	82.0	18.6
	No. 4	33	33	29	90.1	73.0	19.4
	Sample	5	4	2	84.8	51.7	20.9
February	No. 3	19	19	19	92.7	83.8	17.7
	No. 4	19	17	19	89.2	74.9	18.1
	Sample	3	3	3	90.2	52.0	18.7
March	No. 3	39	39	39	90.9	81.9	17.4
	No. 4	23	23	23	89.4	78.2	17.7
	Sample	2	2	2	60.8	35.0	30.0
April	No. 2	11	11	11	92.3	85.4	14.6
	No. 3	36	36	36	91.5	83.8	15.7
	No. 4	14	14	14	86.5	69.4	16.1
	Sample	6	6	6	70.3	44.0	22.3
May	No. 2	41	41	41	91.9	85.0	14.8
	No. 3	24	24	24	88.7	71.5	16.0
	No. 4	7	7	7	84.5	60.0	17.2
	Sample	3	3	3	27.4	21.0	29.2

Figure 23 represents the data compiled in Table XII. The curves denoting monthly average degree of acidity bear the same relation to each other as do the curves denoting monthly average percentage of germination and sound corn.

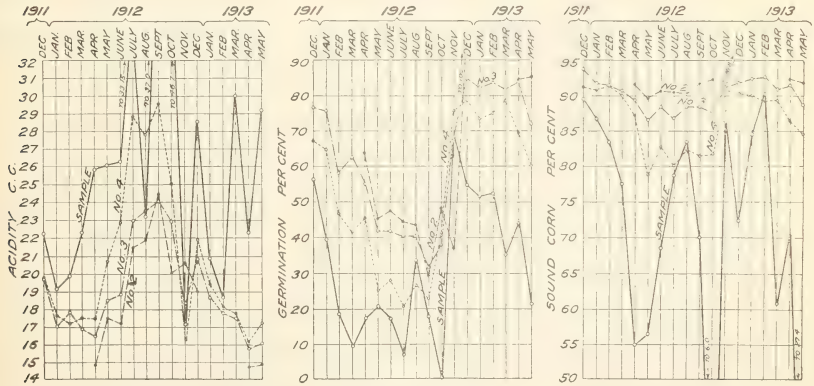


FIG. 23.—Curves showing, by grades, the monthly average degree of acidity, the percentage of germination, and the percentage of sound corn in representative samples of corn received at a principal terminal market (C).

While there is considerable variation between the grades in all the factors throughout the greater part of the year, confusion of the lines denoting little variation and an overlapping of the grades occurs at points indicated as October and November. This is due

to the arrival upon the market of the new crop, when practically all of the corn is graded down because of its excessive moisture and not because of inferior quality.

As already stated, these investigations have shown that 22 c. c. most closely approximates the maximum degree of acidity found to be contained in sound or normally perfect corn.

Table XIII shows the average percentage of sound corn, the average percentage of germination, and the average degree of acidity of each commercial grade. In comparison with these general averages there is likewise shown the relation of the amount of sound corn and the percentage of germination found in samples having a degree of acidity greater than 22 c. c. to the amount of sound corn and the percentage of germination found in samples showing a degree of acidity less than 22 c. c.

TABLE XIII.—*Relation of the percentage of germination and the percentage of sound corn to the degree of acidity found in samples above and below 22 c. c. acidity, by grades, for a year.*

Grade.	Item of comparison.	Number of samples.	Sound corn.	Germination.	Acidity.
			Per cent.	*Per cent.*	*C. c.*
No. 2	General average of all samples	218	90.61	44.40	20.11
	Average of samples above 22 c. c. acidity	63	91.20	28.23	24.21
	Average of samples below 22 c. c. acidity	155	90.60	51.23	18.48
No. 3	General average of all samples	731	88.60	48.80	19.63
	Average of samples above 22 c. c. acidity	171	87.10	30.28	24.84
	Average of samples below 22 c. c. acidity	546	89.38	54.45	18.00
No. 4	General average of all samples	962	87.72	48.60	19.64
	Average of samples above 22 c. c. acidity	185	81.25	25.94	27.44
	Average of samples below 22 c. c. acidity	744	88.15	53.57	17.70
Sample	General average of all samples	230	75.20	32.50	22.42
	Average of samples above 22 c. c. acidity	85	53.58	13.60	30.47
	Average of samples below 22 c. c. acidity	133	87.23	44.90	18.00

Table XIV further establishes the same relationship between the percentage of sound corn, the percentage of germination, and the degree of acidity. In this table, which represents No. 2, No. 3, No. 4, and sample-grade corn, respectively, the samples are grouped by months and the amount of sound corn and the percentage of germination of samples above and below 22 c. c. acidity is compared.

This table shows that less sound corn and lower germinative power were found in the samples which ranged above 22 c. c. acidity. In the lower grades the decrease is more marked in both the percentage of sound corn and the percentage of germination. In the case of No. 2 corn the percentage of sound corn remains quite constant whether the sample showed acidity greater or less than 22 c. c., but the percentage of germination decreases with the increase in degree of acidity. The acid test detects deterioration of the germ where the eye does not, and it discriminates against the kernels of low germinative power.

TABLE XIV.—*Relation of the percentages of sound corn and of germination of samples above 22 c. c. acidity to the same factors of samples below 22 c. c. acidity, by months, from December, 1911, to May, 1913, inclusive, for grades Nos. 2, 3, 4, and sample.*

Year and month.	Acidity above or below 22 c. c.	Grade No. 2 corn.				Grade No. 3 corn.				Grade No. 4 corn.				Sample grade.			
		Number of samples.	Average.			Number of samples.	Average.			Number of samples.	Average.			Number of samples.	Average.		
			Sound corn.	Germination.	Acidity.		Sound corn.	Germination.	Acidity.		Sound corn.	Germination.	Acidity.		Sound corn.	Germination.	Acidity.
			Per cent.	*Per cent.*	*C. c.*		*Per cent.*	*Per cent.*	*C. c.*		*Per cent.*	*Per cent.*	*C. c.*		*Per cent.*	*Per cent.*	*C. c.*
1911.																	
December..	Above .	0	.....	.....	.....	1	91.2	58.0	26.0	10	89.1	62.4	23.1	8	84.4	45.8	28.5
	Below .	0	.....	.....	.....	11	93.8	77.3	19.1	100	91.1	69.4	19.4	19	90.8	60.4	19.6
1912.																	
January....	Above .	0	.....	.....	.....	0	.....	.....	.....	3	87.0	67.3	22.9	1	51.4	22.0	37.4
	Below .	0	.....	.....	.....	65	91.9	75.3	17.0	131	91.1	64.3	17.4	20	90.2	36.6	18.2
February...	Above .	0	.....	.....	.....	1	95.1	2.0	22.2	1	89.6	12.0	24.2	7	60.6	11.1	27.5
	Below .	0	.....	.....	.....	30	91.3	59.8	17.7	110	91.6	47.0	17.1	22	91.2	20.9	17.4
March.....	Above .	0	.....	.....	.....	0	.....	.....	.....	1	76.4	60.0	23.0	5	54.8	11.1	27.2
	Below .	0	.....	.....	.....	59	90.8	62.0	16.9	111	91.0	40.9	17.4	9	89.5	8.2	19.4
April.....	Above .	0	.....	.....	.....	0	.....	.....	.....	0	.....	.....	.....	14	32.0	5.7	31.5
	Below .	6	91.6	63.3	14.8	43	89.3	54.8	16.4	99	87.2	45.5	17.5	12	81.8	31.2	19.3
May.....	Above .	1	91.7	20.0	23.9	5	78.6	24.8	25.1	19	67.3	18.3	24.8	27	43.6	11.7	30.4
	Below .	38	89.8	46.0	17.3	112	86.7	42.0	18.1	59	82.7	27.4	19.4	16	72.3	37.7	18.8
June.....	Above .	1	91.7	12.0	23.2	9	83.7	28.5	23.3	38	80.7	24.0	25.4	8	65.1	10.3	28.9
	Below .	37	90.6	48.3	16.9	105	88.8	42.2	18.4	29	85.4	33.9	19.4	2	82.7	51.0	16.0
July.....	Above .	25	90.9	30.9	23.8	38	86.6	31.7	24.5	30	79.9	17.7	29.8	8	78.9	6.5	33.2
	Below .	34	90.0	54.4	19.8	28	87.5	53.3	20.8	4	81.6	44.0	21.3	0	.....	.....	.....
August.....	Above .	15	88.8	30.8	24.2	38	87.8	27.4	25.6	30	81.8	24.6	28.5	1	76.5	28 0	28.5
	Below .	19	91.1	53.9	20.1	27	89.1	62.3	20.3	4	85.4	42.0	21.5	2	86.8	40.0	21.0
September .	Above .	16	91.7	23.6	25.3	32	88.5	25.8	25.1	34	81.1	22.6	29.5	2	70.0	18.0	37.5
	Below .	4	92.2	51.5	20.6	9	87.6	52.8	20.1	1	89.3	.....	18.7	0	.....	.....	.....
October....	Above .	3	91.5	25.6	23.4	38	87.3	22.5	24.5	13	77.3	27.8	28.2	1	6.0	0	46.7
	Below .	14	92.2	54.1	19.3	23	87.8	64.9	20.2	5	93.1	75.6	16.9	0	.....	.....	.....
November..	Above .	1	91.8	8.0	25.1	9	87.3	33.5	24.2	6	82.4	20.7	28.8	3	43.4	16.0	29.1
	Below .	4	90.8	44.5	19.5	34	92.1	76.3	16.7	91	91.3	79.0	15.4	30	90.2	73.4	15.9
December..	Above .	0	.....	.....	.....	6	96.2	77.7	23.6	15	95.1	80.2	23.7	9	76.8	54.0	28.5
	Below .	1	96.8	100	19.0	19	95.1	85.5	19.9	19	92.5	77.0	20.3	0	.....	.....	.....
1913.																	
January....	Above .	0	.....	.....	.....	1	94.9	76.0	23.6	3	93.9	58.7	22.3	1	82.2	60.0	25.0
	Below .	0	.....	.....	.....	23	95.8	82.0	18.5	26	93.6	74.7	19.2	1	96.9	62.0	16.8
February...	Above .	0	.....	.....	.....	0	.....	.....	.....	0	.....	.....	.....	0	.....	.....	.....
	Below .	0	.....	.....	.....	19	95.4	83.5	17.8	19	93.6	75.0	18.2	3	93.9	52.0	18.8
March.....	Above .	0	.....	.....	.....	0	.....	.....	.....	0	.....	.....	.....	1	34.6	24 0	39.9
	Below .	0	.....	.....	.....	36	93.9	81.8	17.5	23	92.5	78.5	17.8	1	91.7	46.0	20.1
April.....	Above .	0	.....	.....	.....	0	.....	.....	.....	0	.....	.....	.....	3	64.5	43 3	28.2
	Below .	11	95.4	85.4	14.6	36	94.6	83.8	15.7	15	90.3	69.0	16.2	3	83.2	45.0	16.6
May.....	Above .	0	.....	.....	.....	0	.....	.....	.....	0	.....	.....	.....	2	0	4.0	34.8
	Below .	41	94.5	85.0	14.8	24	91.5	71.5	16.0	7	87.7	60.0	17.2	1	83.8	54.0	18.0

Table XV further shows the relation of the degree of acidity of corn to the percentage of germination. Although a test of germinative power could never be used in a practical way in grading corn commercially, except, possibly, in cases of appeal, its value and reliability as a criterion of soundness and quality are, nevertheless, generally acknowledged.

TABLE XV.—*Relation of the degree of acidity to the percentage of germination of samples of corn which arrived at a terminal market from December, 1911, to May, 1913, inclusive.*

Item.	Germination (per cent).				
	0 to 20.	21 to 40.	41 to 60.	61 to 80.	81 to 100.
Number of samples	419	427	560	696	330
Average acidity.....c. c.	24.5	21.1	19.2	18.2	16.7

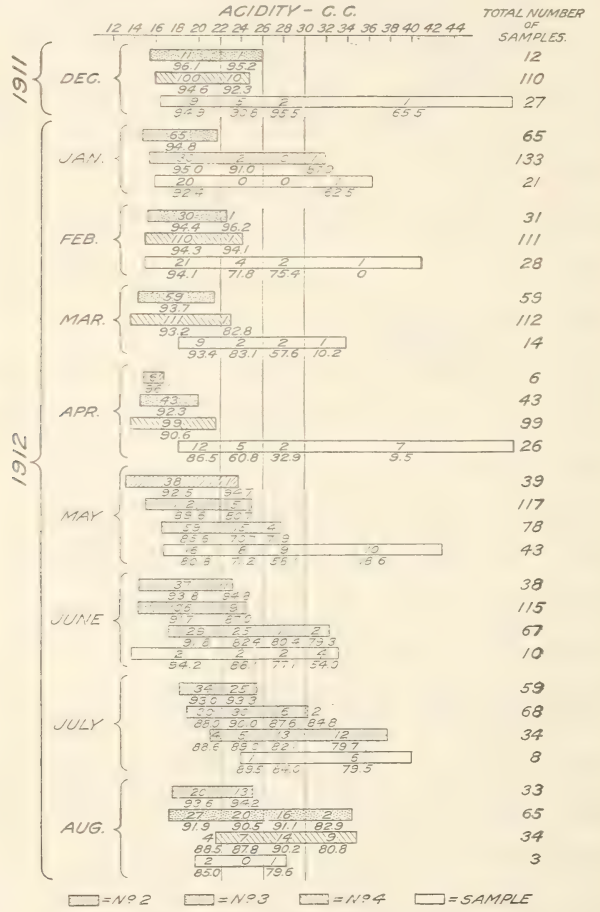


FIG. 217.—Graphic comparison of the increase in degree of acidity with the decrease in percentage of sound kernels found in representative samples of corn as received at a principal terminal market from December, 1911, to August, 1912, inclusive. The individual bars represent the maximum and the minimum degrees of acidity found in each grade. The figures on the bars refer to the number of samples in each grade which fell within the acidity ranges of below 22, between 22.1 and 26, between 26.1 and 30, and above 30 c. c. The number just below the bar refers to the average percentage of sound kernels found in the samples which fell within the acidity range designated.

In the foregoing illustrations and tables the relation of sound corn and germination has been compared with the degree of acidity by showing the average percentage of sound corn and average percent-

age of germination found in samples with acidity greater than 22 c. c. and in samples with acidity less than 22 c. c.

Figures 24*a* and 24*b* serve the purpose of showing the range in the degree of acidity found in each grade, by months. They show, further, by months, the number of samples in each grade with a

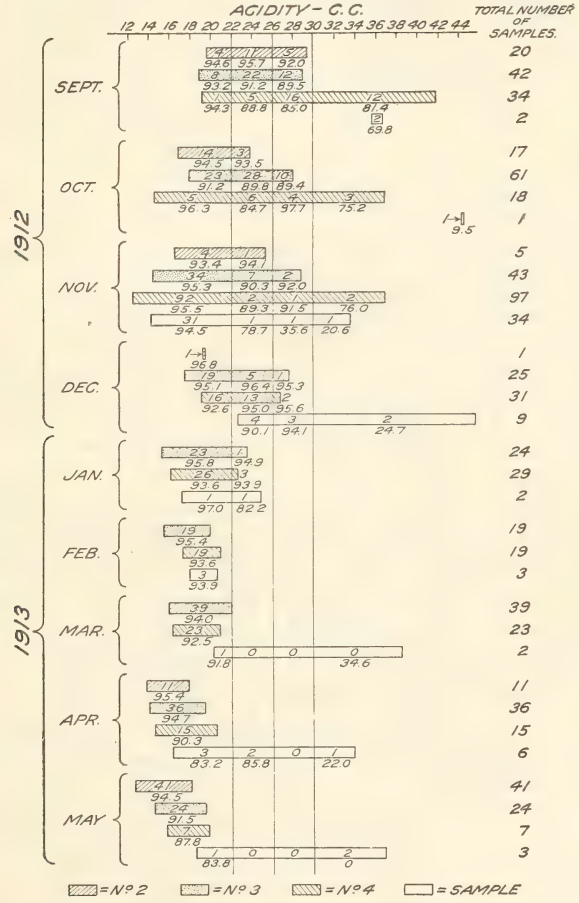


FIG. 24*b*.—Graphic comparison of the increase in degree of acidity with the decrease in percentage of sound kernels found in representative samples of corn as received at a principal terminal market from September, 1912, to May, 1913, inclusive. The individual bars represent the maximum and the minimum degrees of acidity found in each grade. The figures on the bars refer to the number of samples in each grade which fell within the acidity ranges of below 22, between 22.1 and 26, between 26.1 and 30, and above 30 c. c. The number just below the bar refers to the average percentage of sound kernels found in the samples which fell within the acidity range designated.

degree of acidity below 22, between 22.1 and 26, between 26.1 and 30, and above 30 c. c., and also the average percentage of sound corn (including sound broken kernels) found in the samples which fell within these ranges in degree of acidity. Attention is called in these figures to the low percentage of sound corn found in samples within the higher ranges of acidity, to the small range in the degree

of acidity found in samples of the high grades compared with the greater range in degree of acidity of samples in the lower grades, and also to the uniform low degree of acidity of the corn marketed in 1913 as compared to the acidity of the 1912 receipts (crop of 1911). Table XVI represents a summary of figures 24*a* and 24*b*.

TABLE XVI.—*Samples of corn analyzed for acidity at a principal terminal market from December, 1911, to May, 1913, inclusive, showing the average percentage of sound corn and the percentage of the total number of samples falling within stated acidity ranges.*

Samples.	Range of acidity (c. c.).			
	Below 22.	22.1 to 26.	26.1 to 30.	Above 30.
Number of samples	1,909	314	142	87
Percentage of total number of samples	77.9	12.8	5.8	3.5
Average percentage of sound corn found in samples	92.9	88.0	84.4	57.9

RELATION OF COMMERCIAL GRADES TO DAMAGED KERNELS.

By comparing the degree of acidity found in samples with the percentage of damaged kernels found in the same samples by critical mechanical analysis it will be seen that the acid test is a factor in the commercial grading of corn. This fact is clearly brought out in Tables XVII, XVIII, and XIX, and in figures 25 to 33, covering samples representing approximately 2,500 cars received at a principal terminal market.

Table XVII shows the results of acid tests and mechanical analyses for damaged kernels made with samples representing grades No. 2, No. 3, No. 4, and sample, respectively. Attention is called to the increase in the percentage of damaged kernels with the increase in the range of degree of acidity in each grade, and to the uniformly low percentage of damaged kernels found in samples which showed a degree of acidity below 22 c. c., irrespective of the grade.

TABLE XVII.—*Samples of corn analyzed for acidity, showing the percentage which fell within stated ranges, the average heat damage, and the average damage other than from heat of samples in each range.*

Samples and acidity range.	Total samples.		Average damage other than from heat (per cent).	Heat-damaged samples.		
	Number.	Per cent.		Number.	Per cent.	Average (per cent).
No. 2 corn:						
Below 22 c. c.	209	77.1	4.82	2	0.95	2.0
Between 22.1 and 26 c. c.	56	20.6	4.90	0		
Between 26.1 and 30 c. c.	5	1.9	6.13	0		
Above 30 c. c.	0	0				
No. 3 corn:						
Below 22 c. c.	704	79.6	5.9	1	.14	10.2
Between 22.1 and 26 c. c.	131	14.8	7.37	0		
Between 26.1 and 30 c. c.	44	4.9	8.72	0		
Above 30 c. c.	6	.67	13.47	0		
No. 4 corn:						
Below 22 c. c.	853	81.0	5.31		.35	21.3
Between 22.1 and 26 c. c.	95	9.05	12.04	1	1.05	6.45
Between 26.1 and 30 c. c.	65	6.1	17.57	3	4.61	19.0
Above 30 c. c.	40	3.81	18.52	0		
Sample grade:						
Below 22 c. c.	141	58.3	5.21	6	4.25	17.9
Between 22.1 and 26 c. c.	37	15.4	10.66	11	29.72	26.9
Between 26.1 and 30 c. c.	23	9.6	10.91	12	52.17	36.9
Above 30 c. c.	41	16.7	14.94	28	68.29	72.4

The results of the analyses of samples given in Table XVIII show that the degree of acidity of corn increases with the percentage of damaged kernels. Attention is called to the fact that of the samples showing a low percentage of damaged kernels a very small percentage is found in the higher ranges of acidity, while of the samples showing a high percentage of damaged kernels a large percentage is high in degree of acidity.

TABLE XVIII.—*Relation of degree of acidity to the percentage of damaged kernels (exclusive of heat damaged) in samples of corn, as received at a terminal market from April 1, 1912, to October 31, 1912, inclusive.*

Samples.	Damaged kernels of No. 2 corn samples.		Damaged kernels of No. 3 corn samples.			Damaged kernels of No. 4 corn samples.		Damaged kernels of sample-grade corn.	
	With less than 5 per cent.	With more than 5 per cent.	With less than 5 per cent.	With between 5 and 10 per cent.	With more than 10 per cent.	With less than 10 per cent.	With more than 10 per cent.	With less than 10 per cent.	With more than 10 per cent.
Below 22 c. c. acidity, per cent	69.9	71.0	76.2	67.8	60.8	77.1	36.6	85.0	23.0
Above 22 c. c. acidity, per cent	30.1	29.0	23.8	32.2	39.2	22.9	63.4	15.0	77.0
Above 28 c. c. acidity, per cent	0	3.2	1.5	2.8	7.0	7.2	27.9	5.0	44.5
Above 32 c. c. acidity, per cent	0	1.0	0	0	2.1	.6	13.1	5.0	31.1
Average of damaged kernels, per cent	3.13	8.03	3.6	7.22	13.87	6.12	23.7	5.79	27.1
Average acidity, cubic centimeters	19.8	20.2	19.6	20.6	21.4	19.8	26.1	19.4	26.1
Number of samples	126	93	130	242	143	166	197	20	74

Figure 25 summarizes by grades the general relationship that the percentage of damaged kernels bears to the range in the degree of acidity of corn arriving at a principal terminal market. The relationship of the moisture content to these factors is also shown.

To summarize in words, it may be said that corn arriving at terminal markets from country points decreases in moisture content with the advance of the season from harvest to harvest, and likewise there is an increase of damaged kernels and a corresponding increase in degree of acidity, the increase in damaged kernels being due to the deterioration that takes place in the corn while in the crib or in the country elevator, primarily as a result of excessive moisture.

Figures 26 and 27 summarize by grades and by combination of all grades the general relationship that the degree of acidity bears to the percentage of damaged kernels found in samples of corn arriving at a principal terminal market. The relationship of the moisture content and percentage of germination to these factors is also shown. By these curves all factors which determine the quality, soundness, and condition of corn may be compared with the commercial grading of corn arriving at a principal terminal market.

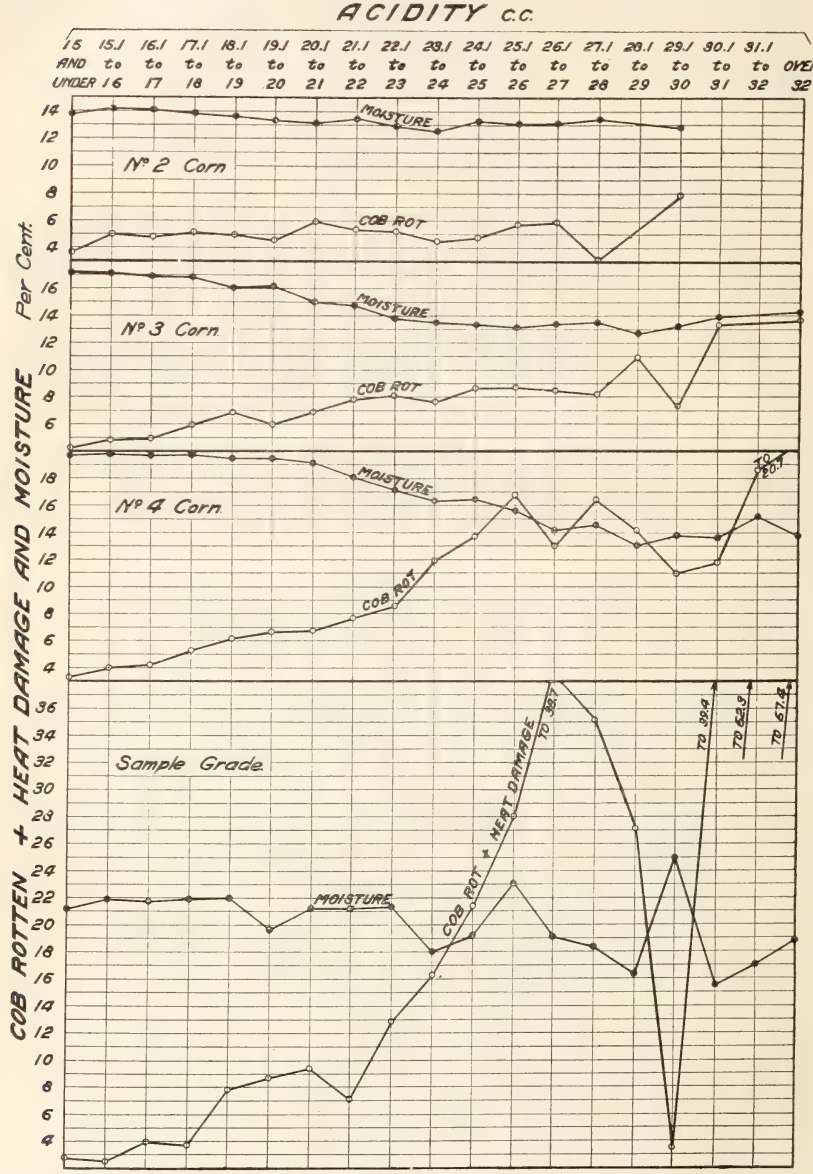


FIG. 25.—Curves showing the relation of the percentages of moisture and of cob-rotten kernels to the degree of acidity in samples of No. 2, No. 3, No. 4, and sample-grade corn as received at a principal terminal market (C).

GENERAL CONSIDERATIONS.

The percentage of moisture in corn is and should be the primary factor in commercial grading. This is due to the fact that the quality of corn from the standpoint of storage and transportation is directly dependent upon the moisture content above certain limits. From the time of harvest until spring (usually April or May, depending upon the season and section of the country) the corn arrives at terminal markets with an excessive percentage of moisture. But after a certain time in the year the great bulk of the corn arriving at terminal markets is without excessive percentage of moisture and the moisture content ceases to be a factor in the grading. Quality and soundness, or the percentage of damaged kernels, then become the primary factors in determining the grade.

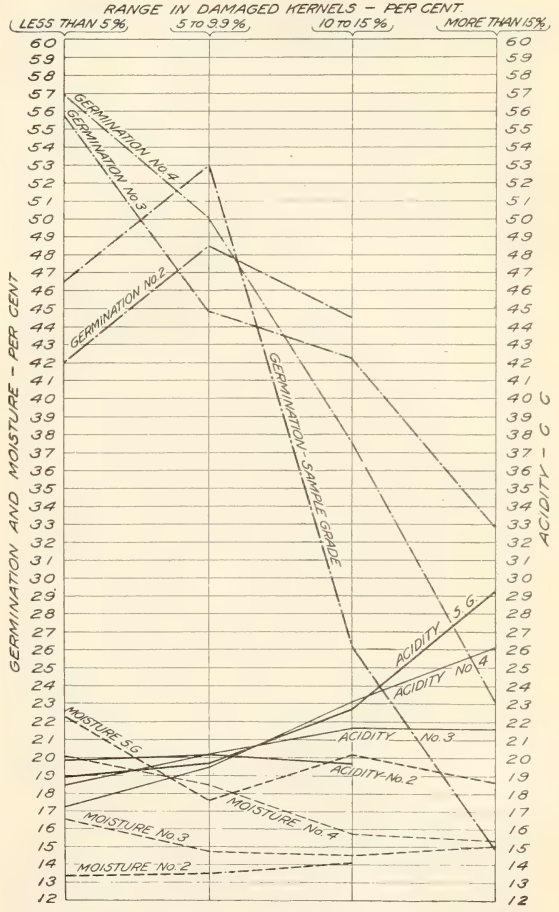


FIG. 26.—Curves showing the relation of the degree of acidity and the percentages of germination and of moisture to the range in percentage of damaged kernels as found in samples representing No. 2, No. 3, No. 4, and sample-grade corn arriving at a principal terminal market (C) from December, 1911, to November, 1912, inclusive.

The degree of acidity of corn, a factor heretofore never used in commercial grading, is nevertheless found to be in direct relation to the degree of quality and soundness as applied to the commercial grades in connection with the range in percentage of damaged kernels found in corn arriving at terminal markets, as shown in figure 28.

The degree of acidity of corn should not necessarily be considered a measure of the percentage of individual kernels that are visibly damaged. It is the soundness and quality of the corn which is indi-

cated by the acidity test, and the results of this investigation suggest the acidity test as a method to be used in determining accurately the soundness and quality of corn.

Let us consider, for example, that a sample of seed corn showed upon test a degree of acidity of 15 c. c. This represents approximately the acidity of the average corn selected for seed. Now, let us consider that a sample of corn consisting entirely of cob-rotten or otherwise damaged kernels showed upon test a degree of acidity of 45 c. c. This represents the degree of acidity of corn selected by the Office of Grain Standardization as being most typical of damaged kernels found in commercial corn arriving at terminal markets throughout the country. Suppose the two samples be mixed in the proportion of 90 per cent seed corn and 10 per cent damaged corn. The degree of acidity of this sample would be theoretically 90 per cent of 15 c. c. plus 10 per cent of 45 c. c., or 18 c. c. This would stamp the sample as being commercially sound corn.

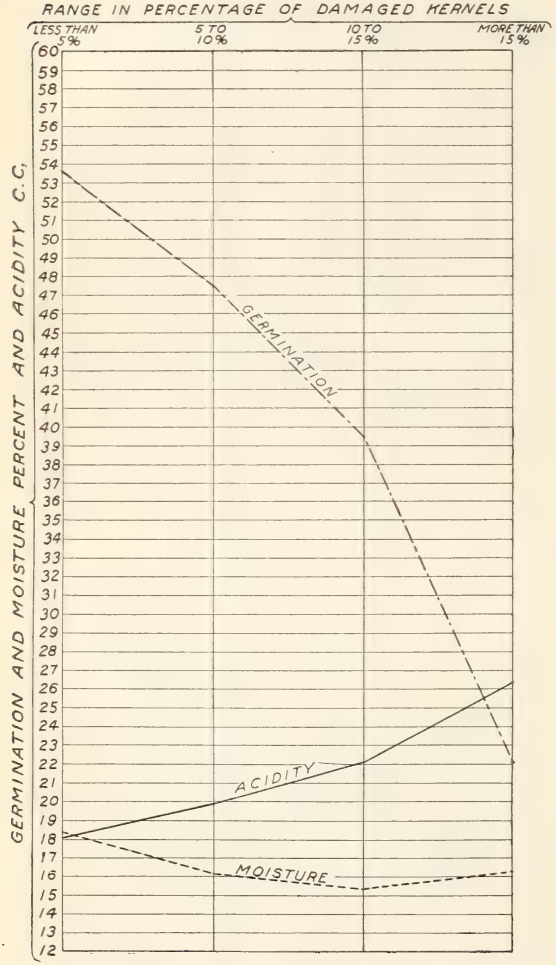


FIG. 27.—Curves showing the relation of the degree of acidity and the percentages of germination and moisture to the range in percentage of damaged kernels as found in samples of corn (average of all grades) arriving at a principal terminal market (C) from December, 1911, to November, 1912, inclusive.

Let us consider further a sample of average sound corn as determined by mechanical separations of samples from several thousand cars of corn arriving at terminal markets. The acidity of such corn is shown by this investigation to be approximately 19.5 c. c. If a sample be

made consisting of 90 per cent of this sound corn and 10 per cent of the damaged corn showing an acidity of 45 c. c., the sample so prepared would show theoretically a degree of acidity of 22.05 (90 per cent of 19.5 c. c. plus 10 per cent of 45 c. c.). This sample would be stamped as being "unsound corn" according to the acid test. The percentage of damaged kernels may vary considerably in corn regarded as sound by the acid test. This is dependent upon the degree of soundness or quality of the kernels judged by the eye as being not damaged.

As a result of this investigation, 22 c. c. is recommended as approximately expressing the maximum degree of acidity found to be contained in corn considered commercially sound. Corn showing a degree of acidity exceeding 22 c. c. indicates the development of excessive acidity through the deterioration of the germ, and is discriminated against as being of poorer quality than corn showing a degree of acidity less than 22 c. c.

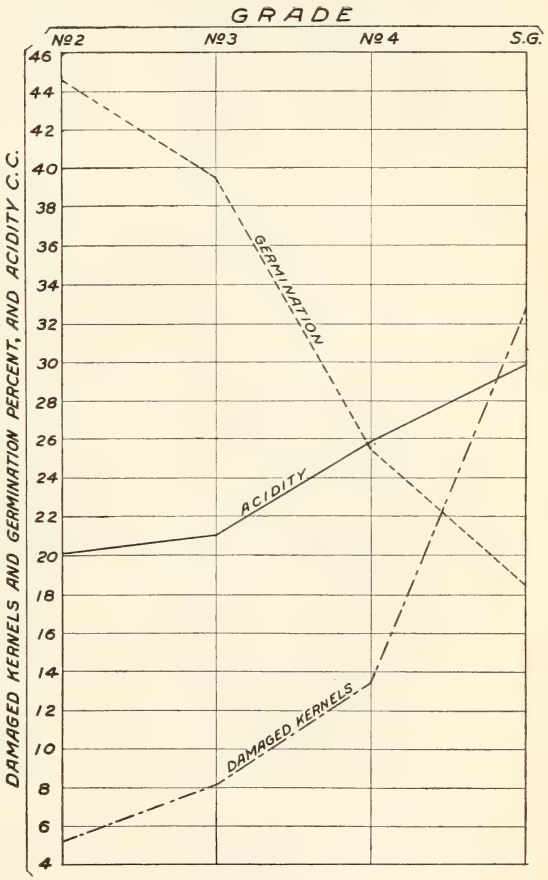


FIG. 28.—Curves showing the increase in the degree of acidity of samples of corn from the high to the low grades where there is also a corresponding increase in percentage of damaged kernels and decrease in percentage of germination, as found to represent approximately 900 cars of corn received at a principal terminal market (C) throughout a year, all of which corn contained less than 16 per cent of moisture and was graded according to quality and amount of damage.

In the determination of soundness and quality of corn by means of the acid test, it is the large bulk of the corn which must be considered rather than the 10 or 15 per cent of damaged kernels which the sample under analysis may contain. The acid test measures definitely the quality and soundness of the 85 or 90 per cent of the so-called "sound kernels," as recognized by the analyst or inspector in his determination of 10 or 15 per cent of damaged kernels by means

of a mechanical analysis. Directed only by his judgment in a mechanical separation of "damaged kernels" from "sound kernels" in any given sample, the analyst is entirely without means of expressing in any standard way the quality and soundness of the sample as a whole. He is, furthermore, entirely without means of confirming his judgment or opinion in his discrimination between sound and damaged kernels by any standard test or criterion.

The results of these corn-acidity investigations indicate that the acid test is such a criterion, and it is offered as an aid to any analyst or inspector who desires to determine in a uniform, standard, and scientific way the quality and soundness of corn.

In order to classify corn as to quality and soundness by means of the acid test, it is necessary to fix certain limits in the degree of acidity, above which limits the corn may be said to be unsound as compared to corn below such limits. It is only in a general, broad way that these limits are suggested. Corn which is to the eye unquestionably of poor quality and unsound shows invariably a high degree of acidity between limits of 30 and 50 c. c. Corn showing above 50 c. c. in degree of acidity is in a very advanced stage of deterioration, and its quality does not need to be tested in any other way than by inspection.

As a result of these and other investigations of the acidity of corn in this country [1] and abroad, a limit of 30 c. c. seems most appropriate in discriminating against wholly bad or unsound corn. Any corn with a degree of acidity more than 30 c. c. is unquestionably unsound and of very poor quality.

Of samples representing approximately 2,450 cars of corn received at a principal terminal market from December, 1911, to May, 1913, inclusive, 87 were found to have a degree of acidity greater than 30 c. c. The results of analyses, together with the commercial grade and the remarks of the inspector who graded the samples, are shown in Table XIX.

TABLE XIX.—*Quality and condition of corn which showed a degree of acidity greater than 30 c. c., as found in representative samples at a principal terminal market.*

Laboratory No.	Month.	Grade.	Moisture.	Cob rot.	Heat damaged.	Germination.	Acidity.	Inspector's remarks.[2]
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*C. c.*	
38496	July	3	13.0	4.00	0	8	30.1	Too much damage.
38665	do	3	14.7	22.60	0	2	30.3	
38498	do	Sample	15.2	0	15.10	4	37.6	Subject; heating.
38520	do	do	15.7	11.00	0	6	33.0	Heating; one end hot.
38531	do	do	14.6	22.25	0	2	35.7	Heating.
38572	do	do	14.6	1.85	5.70	0	33.4	Slightly heating.
38619	do	do	14.8	15.85	0	0	32.8	Heating.
38748	do	do	14.4	44.00	0	0	41.5	Do.
38495	do	4	14.0	15.65	0	0	38.7	Subject; too much damage for 3.

[1] Black, O. F., and Alsberg, C. L. The determination of the deterioration of maize, with incidental reference to pellagra. U. S. Department of Agriculture, Bureau of Plant Industry Bulletin 199, 36 p., 1910.

[2] Explanation of terms: Subject=grade subject to change upon reinspection; mahogany=badly heat damaged.

TABLE XIX.—*Quality and condition of corn which showed a degree of acidity greater than 30 c. c., as found in representative samples at a principal terminal market*—Contd.

Laboratory No.	Month.	Grade.	Moisture.	Cob rot.	Heat damaged.	Germination.	Acidity.	Inspector's remarks.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*C. c.*	
38497	July	4	14.6	17.00	0	16	31.4	Subject; damaged and musty.
38500	do	4	15.0	27.50	0	4	38.3	
38519	do	4	14.7	24.10	0	10	32.3	Too much damage for 3.
38526	do	4	13.3	9.45	0	14	32.1	Do.
38537	do	4	13.1	12.85	0	2	32.9	Do.
38622	do	4	13.3	24.00	0	2	34.4	Damaged and musty.
38662	do	4	14.7	17.30	0	8	32.0	
38689	do	4	13.6	14.40	0	8	33.9	
38749	do	4	13.2	19.75	0	2	35.2	Too much damage for 3.
38757	do	4	14.9	24.10	0	34	35.3	
38760	do	4	14.3	26.25	0	22	32.7	
38977	August	3	13.6	16.50	0	0	32.2	Too much damage.
38998	do	4	13.6	16.25	.....	.....	35.0	Do.
38818	do	4	14.3	17.15	0	.....	35.5	Too much damage for 3; subject.
38855	do	4	15.4	24.30	0	34	31.5	Damaged and musty.
38858	do	4	13.0	25.80	0	8	35.2	
38861	do	4	12.9	10.25	0	.....	30.5	Too much damage for 3.
38873	do	4	14.3	15.75	0	6	31.3	Do.
38902	do	4	12.2	10.50	0	4	33.2	Do.
38926	do	4	13.9	17.05	0	20	32.7	Do.
38927	do	4	13.6	18.35	0	38	31.6	Do.
38979	do	4	13.4	21.00	0	.....	34.2	
39064	September	4	13.7	10.00	0	32	30.7	Do.
39067	do	4	13.4	14.00	0	18	35.0	Do.
39057	do	4	13.4	26.50	0	14	42.3	Dirty and musty.
39069	do	4	14.2	35.00	0	20	39.5	Too much damage for 3.
39096	do	4	13.6	11.15	0	4	30.8	Do.
39115	do	4	13.5	29.70	0	6	43.3	Dirty and musty.
39131	do	4	13.1	12.00	0	10	30.6	Too much damage for 3.
39132	do	4	13.7	15.85	0	4	35.0	Subject; too much damage for 3.
39155	do	4	14.3	10.75	0	18	30.3	Too much damage for 3.
39157	do	4	12.8	9.25	0	2	30.7	Do.
39162	do	4	13.1	19.35	0	36	32.2	Do.
39163	do	4	13.7	14.25	0	6	32.8	Subject; too much damage for 3.
39028	do	Sample	13.0	22.35	.....	14	36.4	Bottom mahogany.
39114	do	do	12.6	26.75	0	22	37.6	Damaged and dirty.
39191	October	4	14.1	13.50	0	.....	34.9	
39192	do	4	14.5	27.75	.....	2	37.8	Too much damage for 3.
39213	do	4	12.9	24.85	.....	32	36.7	Do.
39212	do	Sample	12.7	.....	89.15	.....	46.7	Badly damaged.
39368	November	4	13.6	26.50	.....	4	38.0	Too much damage for 3.
39389	do	4	13.3	16.50	.....	16	30.7	Do.
39409	do	Sample	12.2	27.05	48.80	10	33.8	Badly damaged.
35336	December	do	23.0	34.05	0	32	52.0	Rotten end half.
35875	January	4	20.0	6.70	0	72	32.4	Damp and damaged.
35732	do	Sample	26.3	0	42.40	22	37.4	Wet, hot.
36240	February	do	33.9	0	95.70	0	42.6	Germination wet.
36684	March	do	26.9	0	86.80	0	34.4	Badly damaged.
37406	April	do	21.5	0	97.60	2	33.1	Hot.
37504	do	do	20.0	0	71.80	0	37.7	Do.
37505	do	do	21.5	0	98.70	0	32.9	Do.
37506	do	do	24.1	0	99.00	0	52.0	Do.
37521	do	do	16.2	0	94.15	0	39.8	Heated, sour, and mahogany.
37533	do	do	16.8	89.50	0	2	39.8	Subject; soft, badly damaged, sour.
37536	do	do	14.5	0	53.75	6	33.1	Soft, badly damaged, sour.
37632	May	do	19.0	68.80	0	12	42.4	Subject; soft.
37652	do	do	21.3	.....	98.75	0	44.3	Hot.
37656	do	do	20.0	34.50	0	0	31.9	Do.
37747	do	do	17.9	.....	74.65	6	40.3	Do.
37764	do	do	21.1	.....	97.40	0	37.4	Do.
37785	do	do	20.0	.....	95.15	0	43.1	Subject; too much damage for 3.
37819	do	do	19.1	.....	95.80	.....	37.5	Hot.
37871	do	do	18.6	.....	95.20	.....	39.0	Do.
37905	do	do	17.9	.....	77.65	2	35.3	Do.
37945	do	do	20.6	.....	63.00	4	33.7	Do.
38185	June	4	15.8	22.95	0	2	32.5	Damaged and musty.
38426	do	4	14.6	13.55	0	8	31.0	Too much damage for 3.
38122	do	Sample	14.6	53.75	0	8	31.4	Badly damaged; mahogany.
38242	do	do	15.1	.....	47.25	2	30.8	Badly damaged and musty.
38304	do	do	15.9	19.70	12.00	36	30.3	Heating.
38425	do	do	15.4	17.15	15.22	2	33.5	Do.
39711	December	do	20.4	0	54.10	22	47.7	Hot.
39813	do	do	22.7	.....	93.50	.....	38.0	Subject; hot.
40535	March	do	.....	65.40	.....	24	39.9	
40870	April	do	22.3	78.00	.....	20	34.6	
41119	May	do	.....	.....	.....	4	31.6	
41152	do	do	.....	.....	.....	4	38.0	

Assuming that 30 c. c. correctly discriminates in a general way between good and bad corn, it becomes necessary, in order to make the acid test a test of value, to establish limits below 30 c. c. which will relatively classify the good corn according to its degree of quality and soundness.

Results of corn-acidity investigations show that theoretically quality and soundness vary directly in proportion to the degree of acidity of the corn. All corn shows acidity of a certain degree. The minimum degree of acidity is represented in the corn at the time of harvest, and is found to vary between the limits of 9 or 10 and 15 or 16 c. c., having never been found to exceed 20 c. c.

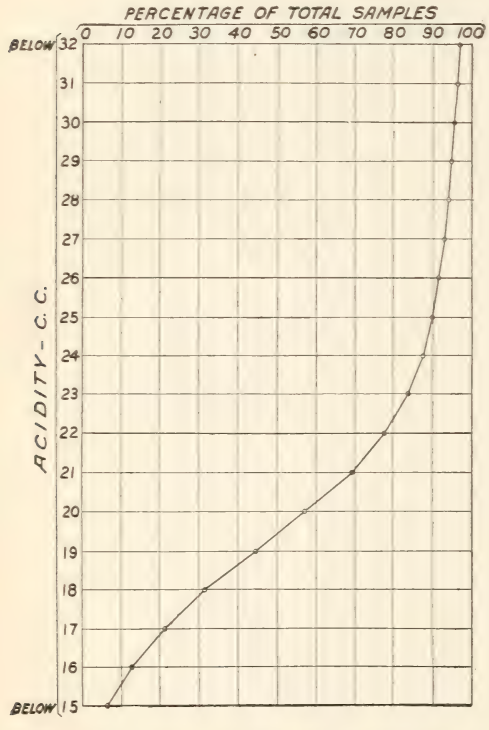


FIG. 29.—Curve showing the percentage of samples of corn tested for degree of acidity which fell below 15, below 16, below 17, and so on up to and including 32 c. c., representing approximately 8,000 cars received at four principal terminal markets.

Covering a period of three years, approximately 10,000 samples were tested for degree of acidity. These samples included seed corn as well as corn from the harvest field, corn as stored on the farm and as found through all stages of commercial handling, including transportation and storage, and showed ranges in the degree of acidity from 9 to 10 c. c. to over 100 c. c. Of the corn arriving at terminal markets throughout the country, between 75 and 80 per cent of the cars as sampled showed acidity below 22 c. c., about 90 per cent was below 26 c. c., and approximately 4 or 5 per cent was above 30 c. c. (Figs. 29 and 30.)

From the results of mechanical analyses of samples representing cars arriving at terminal markets (fig. 21) the average degree of acidity of the separations shows as follows:

	C. c.
Sound kernels	19.5
Broken kernels	22.5
Damaged kernels, exclusive of heat damage	41.2
Slightly heat-damaged kernels	41.8
Badly heat-damaged kernels	50.8

The monthly average acidity of corn considered damaged and the monthly average acidity of corn considered sound, as separated from samples representing approximately 3,000 cars received at a terminal market, compare with the relation of the degree of acidity of corn to its general appearance. (Fig. 31.) It will be seen that the corn appearing sound to the eye was uniformly low in degree of acidity, exceeding the limit of 22 c. c. only slightly in any of the months. Attention is also called to the increase of acidity in both the sound and damaged corn through the summer months, until the arrival upon the market of the new crop.

Of 127 samples of corn selected for seed, only three showed a degree of acidity above 22 c. c., and these samples showed evidence of deterioration through their low germinative power. (Fig. 10.)

With a knowledge of the fact that as corn deteriorates the degree of acidity increases and from the results of investigations as described in the preceding paragraphs, it is believed that 22 c. c. most closely denotes the first stages in deterioration and that any corn showing a degree of acidity greater than 22 c. c. is, by comparison, of lower quality and lacking in normal qualities of soundness which it at one time possessed.

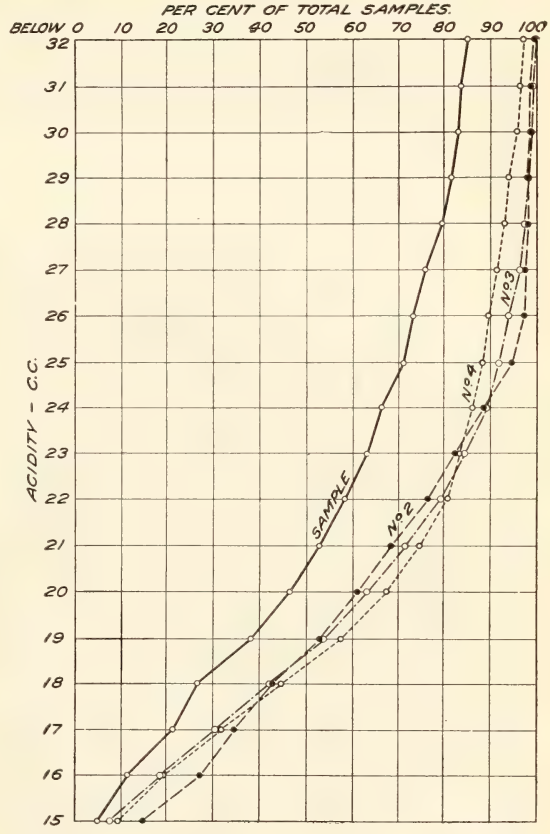


FIG. 30.—Curves showing the percentage of samples of corn in each commercial grade tested for degree of acidity which fell below 15, below 16, below 17 and so on up to and including 32 c. c., representing approximately 2,500 cars received at a principal terminal market from December, 1911, to May, 1913, inclusive.

From the theoretical standpoint it is undoubtedly true that corn with a degree of acidity of 15 c. c. more closely approximates ideal quality and soundness than corn with an acidity of 20 c. c. It has been the aim, however, in fixing the initial limit at 22 c. c. to choose

a limit which would be practical from the standpoint of commercial grading. In the same sense that corn with an acidity of 20 c. c. is of poorer quality than corn with an acidity of 15 c. c., an acidity of 27 c. c. denotes poorer quality and a further advance toward wholly bad corn than an acidity of 25 c. c.

In the commercial classifying of corn according to quality and soundness by means of the acid test, this investigation would recommend but one limit between the limits of 22 and 30 c. c., and that it be placed at 26 c. c.

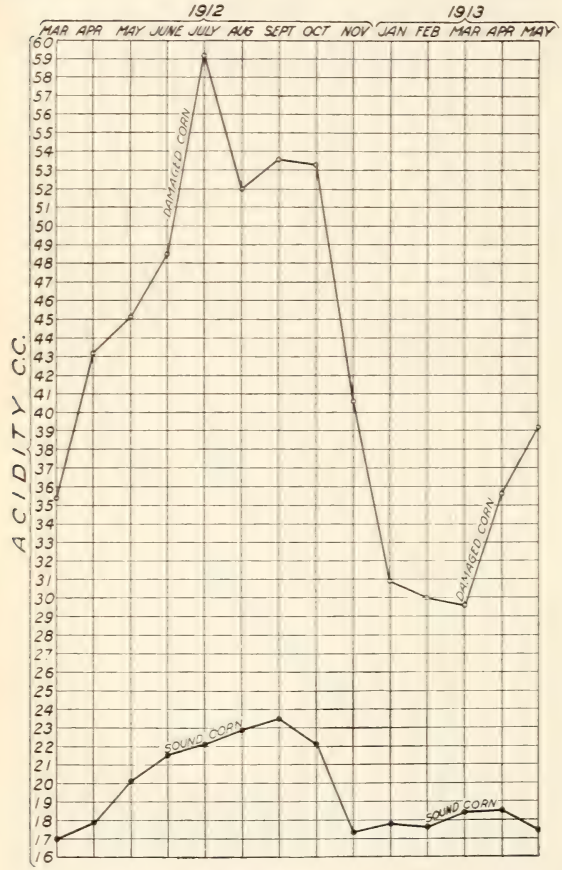


FIG. 31.—Curves comparing the monthly average degree of acidity of sound corn with the monthly average degree of acidity of damaged corn as determined by mechanical analyses of corn arriving at a principal terminal market.

The results of this investigation show that corn with a degree of acidity below 22 c. c. is normally sound and of first-class quality from the commercial standpoint; that corn with a degree of acidity between 22 and 26 c. c. is inferior in quality and soundness, due to deterioration of the germ; that corn with a degree of acidity between 26 and 30 c. c. has deteriorated sufficiently to be considered unsound; and that corn with a degree of acidity greater than 30 c. c. is badly damaged and of a very low quality. It must be remembered in the application of the acid test that the sample as a whole must be considered and not individual kernels.

The question will perhaps arise in the minds of some why the degree of acidity of corn was taken as the one important chemical factor in establishing its condition or quality. The answer to this question will be found in carefully studying Table XX, comparing the change in the different factors throughout the experiment. This

table represents the chemical analysis of a car of corn sampled at various intervals from April 10 to June 26, inclusive, while it was standing on the track at Baltimore. The corn was allowed to heat and go out of condition. For a comparison of the acidity, temperature, and germination during the storage period, see figure 13 (p. 15), which shows that on April 26 the corn was in a badly damaged condition.

TABLE XX.—*Chemical analyses at different stages of deterioration of corn used in a feeding test.*[1]

[The results in columns marked with an asterisk (*) are calculated on a moisture-free basis.]

Date, 1912.	Lab. No.	Moisture.	Ash.*	Ether extract.*	Protein.*	Crude fiber.*	Pentosans.*	Invert sugar.*	Sucrose.*	Undetermined.*	Acidity.	Germination.
April:		*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*C. c.*	*P. ct.*
10	63083	8.99	1.44	4.52	10.23	2.54	6.29	0.15	1.40	73.43	21.3	57.0
10	63084	9.72	1.46	3.98	9.69	2.64	6.42	.23	1.25	74.33	21.9	55.4
10	63085	9.67	1.41	4.35	10.21	2.58	6.70	.24	1.16	73.35	24.3	53.1
10	63086	9.98	1.39	4.50	10.14	2.27	5.94	.23	1.29	74.24	22.7	58.9
24	63181	10.40	1.48	4.58	10.39	2.30	6.34	.22	1.23	73.46	19.6	40.2
24	63182	10.30	1.44	4.33	9.51	2.12	5.95	.20	1.17	75.28	20.9	61.3
24	63183	10.31	1.49	4.36	9.97	2.37	6.45	.07	1.38	73.91	20.3	56.9
26	63254	9.40	1.43	4.45	9.87	2.48	6.78	.34	.95	73.70	19.0	33.1
26	63255	10.20	1.41	4.49	9.50	2.42	6.54	.26	1.12	74.26	19.4	59.2
26	63256	10.42	1.52	4.34	9.52	2.34	6.64	.22	1.17	74.25	19.6	60.3
27	63689	10.54	1.42	4.05	9.71	2.35	6.10	.30	.95	75.12	23.7	38.0
27	63690	10.45	1.44	4.36	9.64	2.22	5.88	.24	1.36	74.86	21.0	52.5
27	63691	11.06	1.47	4.38	9.59	2.24	6.12	.27	1.34	74.59	20.5	51.7
May:												
1	63825	10.12	1.52	3.89	10.05	2.29	5.59	.48	.40	75.78	36.9	11.3
1	63830	10.83	1.49	4.31	9.81	2.22	5.85	.10	1.20	75.02	24.0	65.0
1	63831	11.20	1.51	3.91	10.38	2.33	6.09	.26	1.09	74.43	24.1	54.0
4	63832	11.32	1.45	3.59	9.87	2.76	6.53	.16	1.24	74.40	21.0	54.1
4	63833	10.68	1.47	4.35	10.01	2.41	6.37	.24	1.10	74.05	26.4	44.8
4	63924	10.30	1.35	4.56	9.97	2.37	6.35	.17	.98	74.25	26.3	42.4
10	63923	9.87	1.45	4.15	10.13	2.20	6.27	.23	.90	74.67	29.5	18.9
10	64592	10.74	1.32	4.34	10.02	2.49	6.98	.40	.39	74.06	36.5	10.8
18	64591	10.75	1.47	4.04	10.02	2.66	7.23	.57	.17	73.84	42.4	3.4
22	65113	11.29	1.47	4.02	10.29	2.51	7.06	.47	.17	74.01	41.7	0
22	65114	11.35	1.44	4.18	10.50	2.49	7.39	.49	.19	73.32	44.0	0
25	65191	9.20	1.40	4.24	10.25	2.53	6.39	.39	.06	74.74	40.8	0
25	65192	8.67	1.42	3.87	10.40	2.46	6.02	.35	.08	75.40	46.0	0
29	65209	9.84	1.41	3.75	10.33	2.53	6.25	.26	0	75.47	45.2	0
29	65210	9.82	1.36	4.15	10.32	2.63	6.33	.47	.10	74.64	44.6	0
31	65341	9.59	1.45	3.96	10.30	2.58	6.50	.42	.32	74.47	47.6	4.4
31	65342	9.98	1.49	3.96	9.72	3.69	6.56	.46	.08	74.04	44.4	0
31	65346	10.40	1.50	3.83	9.98	2.51	6.58	.22	.42	74.96	37.5	7.8
31	65347	10.15	1.47	4.06	10.57	2.36	6.44	.38	.35	74.37	40.9	10.0
June:												
1	65352	10.67	1.44	4.00	9.79	2.62	6.66	.36	.29	74.84	40.5	7.8
5	65398	10.41	1.52	3.69	10.60	2.47	6.67	.36	.19	74.50	43.5	0
8	65461	11.14	1.52	3.76	10.28	2.35	6.37	.38	.12	75.22	44.8	0
12	65525	10.79	1.49	3.84	9.81	2.51	6.74	.42	.07	75.12	45.5	1.1
12	65542	11.53	1.61	3.80	10.11	2.19	5.82	0	.35	76.14	46.5	0
19	65593	10.94	1.52	3.63	10.45	2.61	6.66	.30	.09	74.74	50.8	0
25	65639	10.58	1.48	3.67	10.21	2.67	6.34	.40	.21	75.02	57.9	2.2
25	65640	11.03	1.51	3.62	11.66	2.53	6.63	.43	.01	73.61	48.1	0
26	65644	10.75	1.50	3.79	10.43	2.62	6.38	.33	.13	74.82	55.6	3.3
26	65650	9.47	1.47	3.88	10.28	2.50	5.79	.29	.18	75.61	49.0	0
Average		10.35	1.46	4.08	10.11	2.48	6.40	.30	.63	74.54	34.7	24.3

[1] The writers wish to express their appreciation to Mr. G. L. Bidwell, Chief of the Cattle Food Laboratory, Bureau of Chemistry, for making many of the chemical analyses here shown.

Now, compare the factors in Table XX from April 10 to June 26, 1912, and it will be found that the only factors showing a perceptible change are the acidity and sucrose, while the ether extract has a

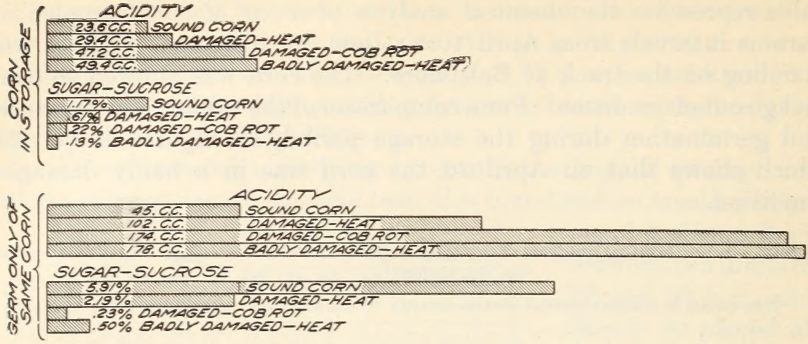


FIG. 32.—Graphic comparison of corn under various stages of deterioration, showing (1) that the degree of acidity is proportional to the degree of deterioration, (2) that where there is an increase in the degree of acidity there is a corresponding decrease in the amount of sugar, and (3) that the source of the increase in the degree of acidity is mostly in the germ.

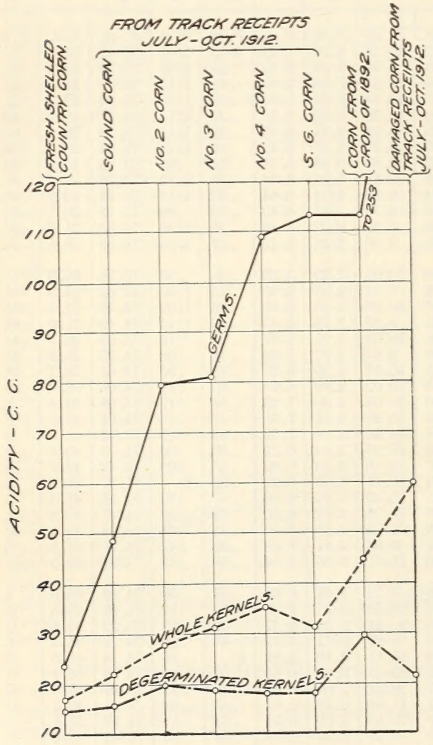


FIG. 33.—Curves comparing the degree of acidity of the germs of corn with that of the degerminated kernels and with that of the whole kernels, showing that the cause of the high degree of acidity in unsound corn is due to the development of abnormal acidity in the germ.

general tendency to become lower. This is as one would expect, because it is through the decomposition of these constituents, ether extract (fats and oils) and sugars, that acids are formed. All the analyses in columns 4 to 11 of the table have been calculated on a moisture-free basis.

Figure 32 represents corn under various stages of deterioration made from the results of a special storage experiment. It shows that the amount of acid is proportional to the degree of deterioration and that where there is an increase in the amount of acid there is a corresponding decrease in the amount of sugar, and it also shows that the source of the increase in the amount of acid is mostly in the germ.

Figure 33 represents the acid determinations of some of the component parts of the corn kernel and again shows that the seat of most of the acid, and especially the increase in acid, is in the germ.

SUMMARY.

As a result of these corn-acidity investigations, the following facts are well established:

(1) All corn, unless in a state of putrefaction, contains acid-reacting substances which impart to the corn a certain degree of acidity.

(2) There is a great variation in the degree of acidity of corn, ranging from 9 or 10 c. c. to over 100 c. c. The degree of acidity can be determined by the acid test to within 0.5 c. c.

(3) The source of corn acidity is mostly in the germ. The source of increase in the degree of acidity is almost entirely in the germ.

(4) All corn judged damaged by the eye is higher in degree of acidity than corn judged sound by the eye.

(5) In a general way the degree of acidity of corn varies inversely with the germinative power.

(6) The degree of acidity of corn increases directly with the percentage of damaged kernels as determined by mechanical analyses.

(7) The degree of acidity of corn is greatly increased by the action of fermentation and high temperature.

(8) Throughout the year, from harvest to harvest, there is a gradual increase in the degree of acidity and a corresponding decrease in the percentage of germination of corn arriving at terminal markets.

(9) With respect to quality and soundness, the degree of acidity of corn is commensurate with the commercial grading at terminal markets.

(10) The degree of acidity of corn is a criterion of soundness and quality.

(11) From the standpoint of commercial grading, corn with a degree of acidity less than 22 c. c. is normally sound and of good commercial quality; corn with a degree of acidity between 22 and 26 c. c. is somewhat inferior in quality and soundness, due to deterioration of the germ; corn with a degree of acidity between 26 and 30 c. c. evidences marked deterioration and is unsound; and corn with a degree of acidity greater than 30 c. c. is badly damaged and should be considered from a commercial standpoint as sample-grade corn.

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